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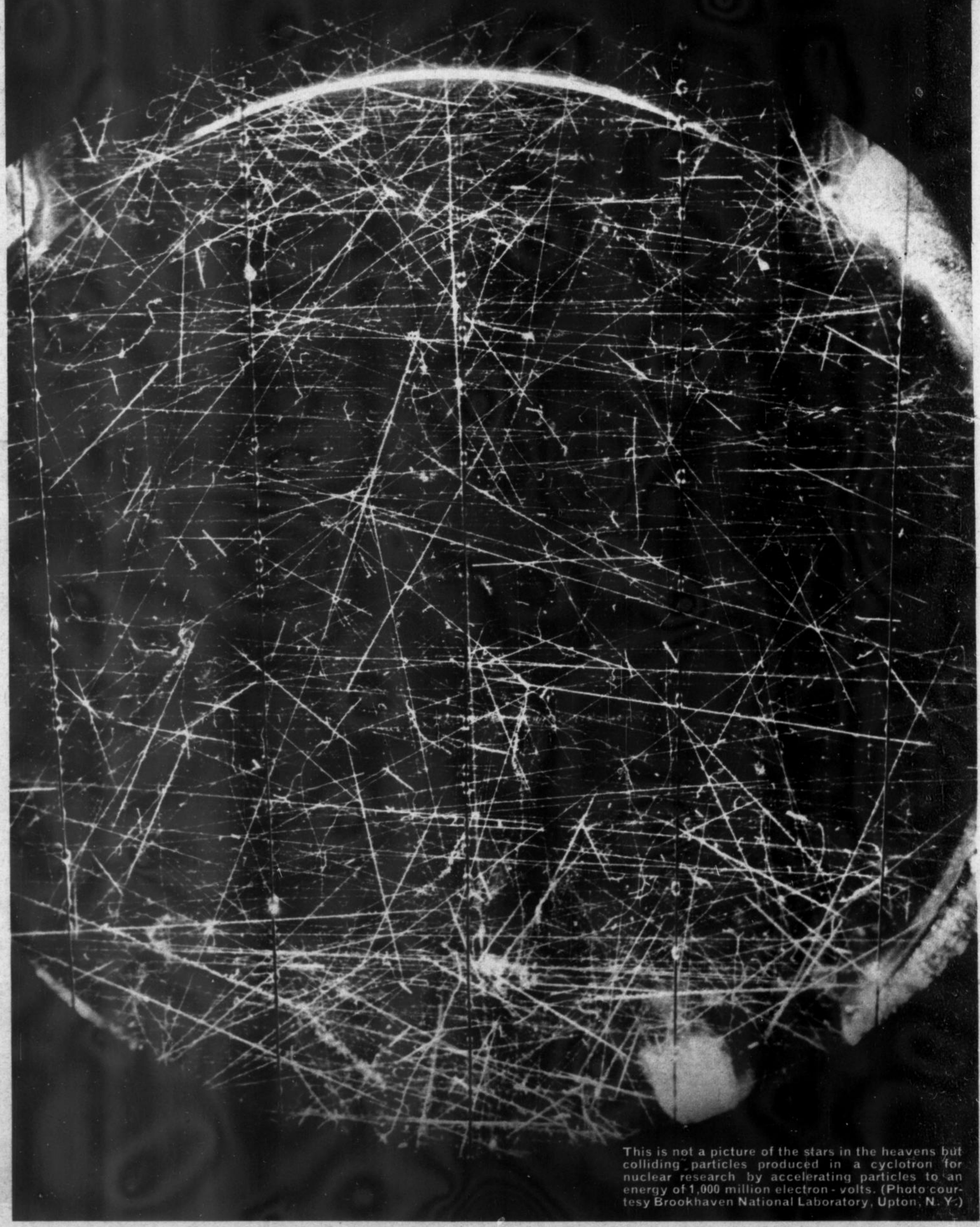
THE WORLD WITHIN THE ATOM



This is not a picture of the stars in the heavens but colliding particles produced in a cyclotron for nuclear research by accelerating particles to an energy of 1,000 million electron - volts. (Photo courtesy Brookhaven National Laboratory, Upton, N. Y.)

SCIENCE PROBES THE SECRET OF THE MYSTERIOUS ATOM

As long as man has been on the earth he has been an explorer and has expanded his world. For centuries the scenes of adventure were on the earth's surface, with the science of geography mapping the conquests and making them useable. Now that the entire surface is familiar, explorers have turned to the depths of the sea and the heights of the sky. The first plane left the ground in 1905 and by 1950 rockets had soared upward 250 miles, as far straight up as London is distant from Paris. Today boys dream of flying to neighbouring planets. Meanwhile great telescopes have made the twinkling stars real and beyond the stars the distant galaxies are now being counted and mapped. Our imagination reaches upward and outward beyond the sky, as in former days it played on unknown lands beyond the sea.

All this is well known. But few persons understand that exploration has also gone far in the opposite direction : inwards. It is harder to visualize because the materials around us—wood and stone and metal—seem so solid. Yet within these and all other materials are molecules and within them are atoms and, in turn, within the atoms are still smaller particles, the proton, the electron and many more. There seems no limit to smallness, and research explores ever inward into the smallest as it does outward into the great universe.

This is the scene of today's adventures and exploration, as thrilling as any geographic or spatial expedition, and as important to man's future life. It is important that people everywhere open their minds to it and become familiar with the facts. For here is a strange world where solid matter turns out to be almost empty, where particles move at incredible speeds, where they even disappear and become energy, where energy itself is composed of particles, and where time is measured in millionths of a second. But once these new conceptions are accepted and a few new words are learned there is nothing too complicated to understand—unless one has the curiosity to master the atom completely and, in that case, thorough mathematical study is essential.

There is one important reason why the world within the atom must be better known. That is because popular ignorance of the subject has given the atom a bad name. To the vast majority atomic energy means horrendous explosions and the frightful weapons that could wipe out civilization.

It is the tragedy of this new science that it happened to come to fruition in 1939 just when the last great war began and it was almost immediately put to work to increase military power. It was wholly unknown to most persons when the first atomic bomb was exploded and so it burst on mankind with an unforgettable shock. And it should not be forgotten. Yet this military use—or misuse—of the new knowledge is only one special aspect, forcibly developed by war.

To ignore the entire science with all its possibilities for the good of mankind is like closing one's mind to all aviation and all peaceful uses of the airplane because, during the war, aviation provided the merciless bomber. There is little attitude of fear and horror today toward the airplane. So too there is a world of benefit in the medical, industrial and agricultural uses of the atomic rays. There are revelations on the nature of matter and the structure of the universe. There are the beginnings of many new sciences and the indications of a good life in the years to come for our children, if not for us.

It is today fully as important to know about the particles within the atom as it was to learn about the mysterious new America centuries ago, or about Pasteur's discovery of the germs that cause disease two generations ago, and about the invention of the airplane fifty years ago. The frontiers of man's knowledge are now within the atom.

This series of articles has the purpose of bringing this new world to the schools, of answering the questions that children today ask their teachers and their parents. It is a story to explain why Unesco called together the experts in atomic science from the European nations to co-operate in researches on atomic structure and on high-energy particles, since the costs are almost too high for any one nation to bear alone. European students and scholars can soon have facilities equal to the best since twelve nations have recently joined to create the European Council for Nuclear Research (called CERN from its initials in French), with a great new laboratory in the city of peace, Geneva.

And so this is a story of international co-operation in explorations at the borderland of man's knowledge. It is a story that should help to make the new words—like cosmic rays, protons, and mesons—familiar in the common speech of all nations. Its purpose is to help incorporate the world within the atom into the common culture of mankind.

But there is no discussion in these articles of bombs, of plutonium, or of atomic reactors and piles. Those are military applications of this new knowledge and they represent only a small and specialized application of the new science, largely secret and perhaps only temporary. In these uses the atoms are destroyed by fission and their matter is violently converted into explosive energy.

This is a very different subject from the cosmic rays that reach earth from outer space, from the wondrous uses of radium in curing disease, and from the inspiring new conception of the atom as a universe in itself, as complex as a galaxy of stars, filled with unknown radiations, alive with action, of particles within particles, and of puzzles wrapped in mystery. Explosive fission for military purposes is a misuse, born of man's incapacity in social and international affairs. It is not a necessary nor a legitimate part of man's new knowledge of nature.

The scientific facts and principles explained on these pages are not only the property of all mankind and the result of research in many nations, but are truly an expansion of man's universe. As the great explorers mapped the earth, and the astronomers chart the sky, so the atomic scientist, delving into matter and energy, has discovered an unknown world that is a revelation for philosophers and a vast resource for fortune generations. No educated person can afford to ignore them.

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EDITORIAL OFFICES:
UNESCO, 19, av. Kléber, PARIS-16

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Editor-in-Chief: S. M. KOFFLER
EDITORS { English edition: R. S. FENTON
French edition: A. LEVENTIS
Spanish edition: J. DE BENITO

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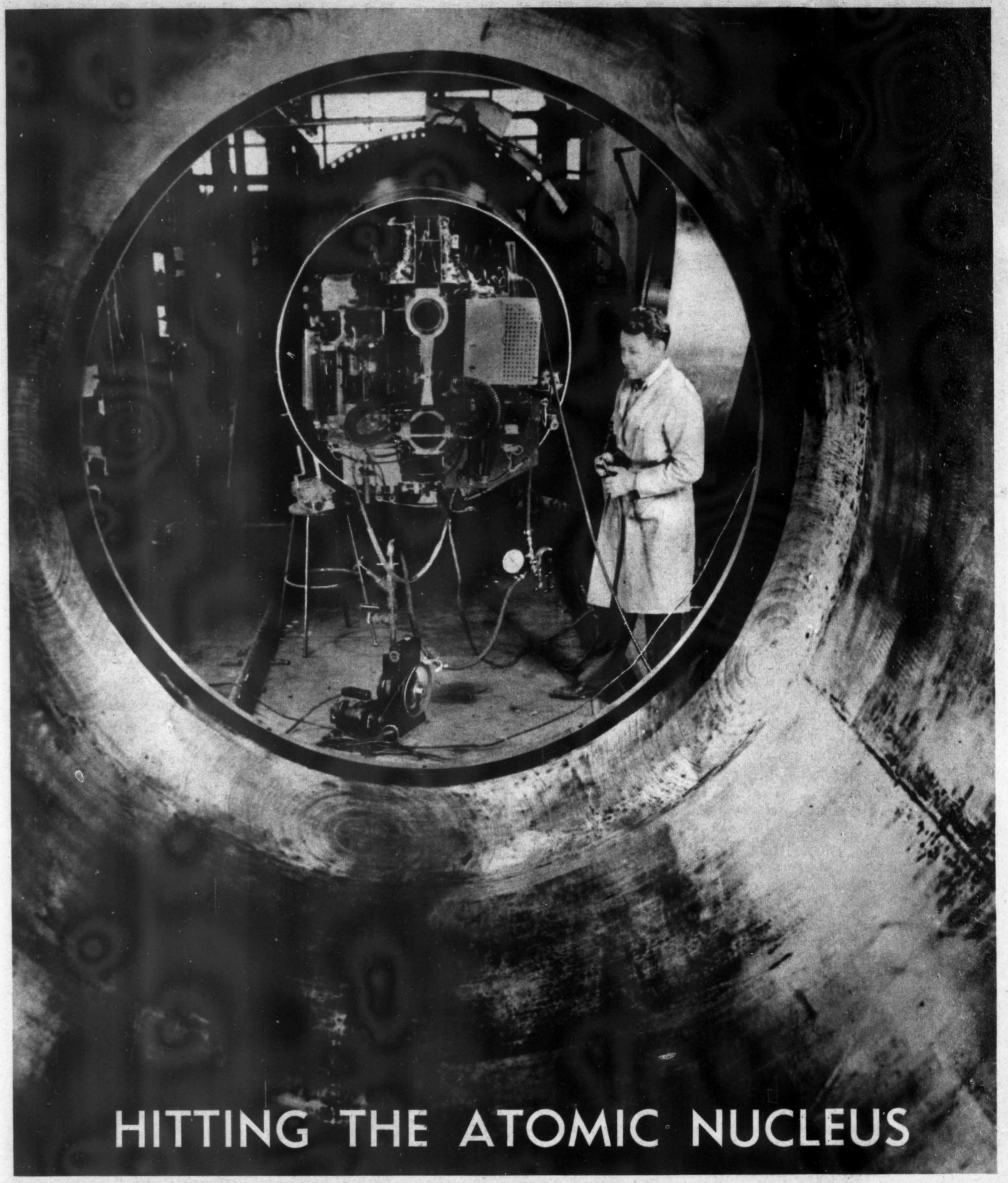


HITTING THE ATOMIC NUCLEUS

Radioactive elements, such as radium, emit high-speed particles, both electrons and protons, but in small quantities. For the exploration of the structure of the atomic nucleus a powerful stream of very high-energy electronic or nuclear projectiles is needed. The photograph shows a Van de Graaff generator of such particles, detached from the large shell in which particles are given high velocity and become projectiles which can be effectively used for the bombardment of atoms.

By Dr. Lew Kowarski
Director of the Laboratory Group,
European Council for Nuclear Research

HUMAN activities consist largely in pulling apart the objects found in Nature and putting together again the materials thus obtained. Huge forests melt under the lumberjacks' axes and come to life again as Sunday papers and rayon stockings; iron ore deposits combine with rubber plantations and oil pools to produce the noon-hour traffic jam ; stone quarries reappear as houses. Man learns quickly enough that the process of pulling apart becomes increasingly difficult as the size of its object decreases.

From the earliest times, it was possible to distinguish two quite different levels on which the separating and rebuilding operations could take place. At the nearer level, the objects, ranging from pyramids to grains of dust, exhibit dimensions comparable to the human size. Here the processes are mechanical and the tools consist of the human hand with its multiple extensions from the sharpened flint to the watchmaker's drill. Energies which can be spent in handling a pound of matter are still on the scale of human strength.

Operations which we today call "chemical", but which started as early as the invention of fire and agriculture, occur on a quite different level. We know today that every chemical process consists in separating and re-arranging material objects which are so small that in the tiniest visible speck or drop of matter they still number in billions of billions.

To separate these objects—we call them atoms and molecules — from one another, we have to exert a considerably greater energy than on the previous level, and when we bring them to rest in a new arrangement, similar amounts of energy may be recovered. To hew a kilogram of coal out of a coal seam (a mechanical operation), the necessary exertion amounts to but a small figure, when expressed in some usual unit such as the kilogrammeter. But the act of burning this same kilogram (a chemical operation) produces 3 million kilogrammeters.

The human mastery of chemical forces, as instanced in the technology of fuels, alloys or synthetic materials, became fairly complete during the last two centuries or so; but as the art of separating and recombining the atoms improved, the first intimation appeared (about 60 years ago) that the atoms contained within themselves still smaller structural units. This recognition amounted to a new challenge—how to take the atom apart — and a new promise, that of an immense new store of energy which could be gained on that new level of re-arrangement.

The taking apart came first. To concentrate enough energy in the volume of a single atom, no human tool is fine enough; the only thinkable agency is the impact of very small projectiles moving at a high speed. When a highly accelerated atom collides with another, the effect is that of a heavy hammer blow, and if the hammer carries suffi-

(Cont'd on next page)

SEPARATING AND THEN RE-GROUPING THE TINIEST SPECKS OF MATTER

(Continued from previous page.)

cient momentum, the anvil can be smashed. The first operation of this sort was produced in 1919; the atomic tools were not yet human-made—use was made of the fact that some naturally occurring substances, called radio-active, have the property of ejecting streams of fast-moving atoms.

In 1932 this natural propulsion was superseded by human machinery in which it became possible to subject atoms of hydrogen, helium, etc... to very strong electric and magnetic forces. With the help of machines—cyclotrons, Van de Graff generators etc—research on subatomic, "nuclear", forces became rapid and effective.

It was quickly recognized that all atoms were built up of two main types of bricks—protons and neutrons — and that the forces involved in the combination of these bricks were enormous. In fact, in addition to the mechanical and the chemical levels of human interference, a third level was discovered, involving energies millions of times greater than those found on the chemical level.

These energies are often mentioned in terms of a special unit—the electron-volt (written eV), which requires a few words of explanation. A chemist likes to know the amount of energy contributed by a *single atom* in chemical processes such as burning. Such amounts are very small and a very small unit is convenient when describing them; in the combustion of coal, one atom contributes about 4 eV.

Mothballs versus atoms

To be effective in nuclear processes, a single atom has to carry a few *million* eV (written MeV). Forces which, on the customary human level, are distributed among millions of atoms, have to be concentrated on a single one to enable it to deal a (nuclearly) telling blow on the target. So we need powerful and intricate machinery.

During the first ten years of their studies on this level, the nuclear physicists could only hurl streams of atomic bullets on their targets and observe the rather few collisions which took place under these conditions. This method was somewhat reminiscent of the famous story according to which mothballs are quite effective against moths if only you throw them adroitly enough to hit the beasts in full flight. The disproportion between the huge machinery used in nuclear research and the negligible combined weight of all the target atoms affected by the lucky projectiles was enormous, but even the few hits scored in this manner yielded a great deal of information about the nuclear forces involved, and the nuclear physicists were kept happy in their impractical pursuit.

The situation changed during the War, when a way was found to produce in uranium a new kind of reaction capable of being transmitted to neighbouring atoms of the same element. It was as if a mothball had been invented capable of infecting a moth with a quickly catching plague. The way was found to release in a kilogram of matter energies several million times greater than those obtainable by chemical processes, and a new chapter was opened, for better and for worse, in the history of human control of natural forces.

For the nuclear physicist, this tremendous by-product of his ingenuity was but a small entry in the log-book of his voyage into the unknown. A new aim and a new level of minuteness began to glimmer before his eyes: protons and neutrons themselves gave signs of willingness to be taken apart. A swarm of tinier moths began to haunt the nuclear researcher's imagination and spurred on his quest for swifter and surer mothballs.

By 1945 ways were found to speed the atom-sized tools — still the same gaseous atoms, preferably hydrogen — to hundreds (and, by 1952, to thousands) of MeV, thus reaching levels far above those which, a few years earlier, led to the discovery of the peculiar property of uranium. Today the fission of uranium, the peaceful piles and the not-so-peaceful stockpiles are a chapter which offers little professional interest to the nuclear researcher and which he is inclined to leave to his chemical, metallurgical and engineering colleagues. The forefront of nuclear research has moved into still higher concentrations of energy into still smaller volumes, and in doing so has again become happily impractical and remote from immediate applications, lethal or otherwise.

Superhuman sources of energy

It cannot be said that on this "metatomic" (beyond the atom) level every phenomenon was a novelty. For the past forty years a mysterious agency, apparently coming from the outer space, was known to affect the sensitive measuring devices used by the nuclear physicists. These "cosmic rays" were found to carry concentrated energy, sometimes comparable to that obtained from either radio-active or human-made propulsive machinery, and sometimes far more powerful than anything that human means could conceivably contrive.

For a generation, no phenomenon involving more than a few MeV could be produced in a laboratory; observers had to climb mountains or fly balloons, and gather a scanty harvest of cosmic-ray manifestations. Today thousands of MeV are open to experimentation and tomorrow the boundary of the human-made phenomena will be pushed still further into the realm of cosmic-ray induced effects.

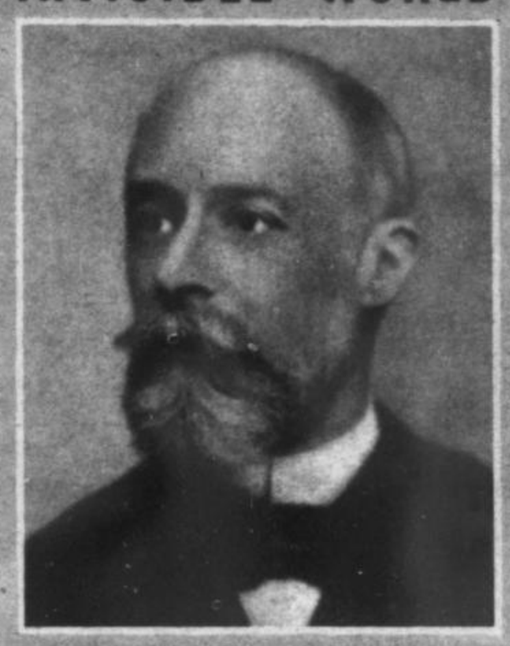
In this ambitious and yet disinterested pursuit, our American colleagues had, so far, the advantage of having at their disposal all the biggest and most modern nuclear machines. With the creation of CERN and its plans of building two powerful sources of very highly accelerated atoms, European scientists hope to be able soon to resume their place on the advancing front of knowledge.

There will be new discoveries, some of which later on may lead to new applications, as different from what we call now "atomic technology" as this technology is different from chemistry. Knowledge brings fruit, but it is in his quest for knowledge itself that the scientist is learning to hit the atomic nucleus with increasingly sharper and more effective blows.

PIONEERS OF THE INVISIBLE WORLD

WILHELM L. RŒNTGEN
(Germany)

Father of research on penetrating and invisible rays. Discovered X-rays in 1895 thus opening the way to the rapid discovery and use of radioactivity.

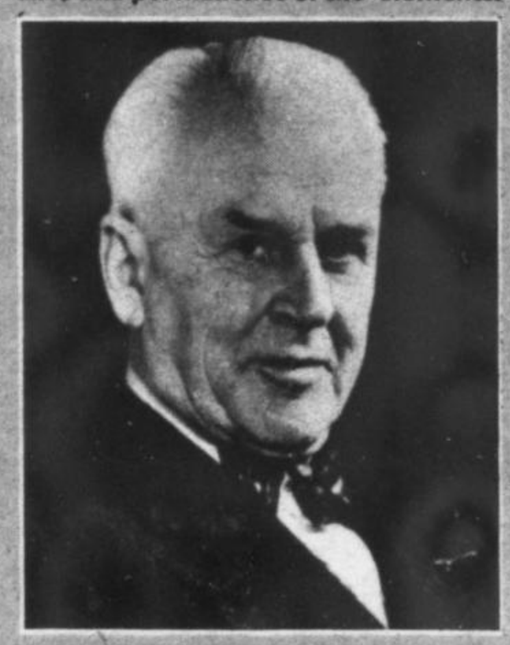


HENRI BECQUEREL
(France)

His experiments with uranium led to discovery of radioactivity in 1896, thus destroying the idea of the independence and permanence of the elements.

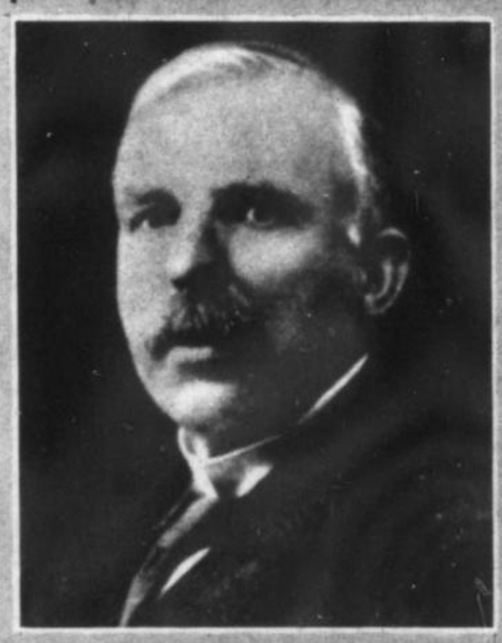
PIERRE AND MARIE CURIE
(France)

Their discovery of radium in 1898 was the first revelation of what we now call atomic energy and definite proof that the atom has an interior.



ROBERT A. MILLIKAN
(United States)

The first to measure the mass and charge of the electron in 1909. He thus proved in the laboratory that an electric current is a stream of electrons.



SIR ERNEST RUTHERFORD
(New Zealand)

Showed that atomic transformations can be man-made. In 1919 he achieved the old alchemists' dream by changing nitrogen atoms into oxygen.

ERNEST O. LAWRENCE
(United States)

Designed and built the first cyclotron, a machine for accelerating nuclear particles to a high energy so they can be used for atom-splitting experiments

NIELS BOHR
(Denmark)

One of the great living nuclear theorists. His was the first successful theory of atomic structure to explain chemical and spectrascopic phenomena.

ENRICO FERMI
(Italy)

The first investigator to use neutrons to split atomic nuclei. Neutrons have been found to be the most powerful and penetrating of atom-splitting tools.

UNLOCKING THE BASIC SECRETS OF NATURE

1 ALPHA, BETA, GAMMA — THE ABC OF NUCLEAR PHYSICS

by Dr. Gerald Wendt,
Head, Division of Science Teaching, Unesco.

THE greatest surprise experienced by the student of the universe is to find that it is composed entirely of discrete particles. If one could step quite outside it, the whole great universe would look somewhat like a wisp of mist or a puff of smoke, with stars and galaxies in place of the droplets of water in the mist. The stars too, like the sun and the earth, are composed of materials in the solid, liquid or gaseous state, and these in turn are composed of very small particles, known as molecules.

Solid rock and metal, the oceans, and the atmosphere around us are not continuous, as they seem to our eyes, but are made up of individual molecules. In solids they are held in firm contact to each other; in liquids they are loosely held so that they easily slide over each other, or flow; in gases they are quite separate, with empty space between them. Temperature decreases their attraction for each other so that heating ice first melts it to liquid water, then boils it to steam, with the molecules separating ever farther from each other. This much has been known for centuries and is new only to the beginner in the science of physics.

The molecules are all alike in each of the many thousands of different substances that compose the earth: sugar and salt, sulphur and iron, cellulose and protein, limestone and sand. They are ultimate in the sense that they cannot be split into smaller particles mechanically. But the chemist can split them by putting different substances in contact with each other in which case reactions take place that give rise to new materials. Thus heating oil or cellulose in air starts combustion, to form water and carbon dioxide. This, with other experiments, shows that within the molecules of the oil and the cellulose there are both carbon and hydrogen, both of which combine with the oxygen of the air to give the oxides — for water is merely the oxide of hydrogen.

Such reactions, and myriads more complicated, have proved that molecules are composed of still smaller particles, the atoms of the chemical elements. There are 92 different elements, thus 92 different types of atoms, which in various combinations form the endless variety of molecules and therefore the whole range of different materials that compose the earth and the universe — including the materials that compose living things and the bodies of animals and men. As physics studies molecules and their motion, so chemistry studies atoms and their combinations with each other to form molecules.

For a century after their existence was accepted by scientists, atoms were considered to be the ultimate building stones of all matter. No one suspected that they had an interior. That would have been almost unthinkable in the philosophy of the nineteenth century. But in the final years of that century came the revelation. In 1896, Henri Becquerel in Paris noticed, almost by accident, that uranium fogs a photographic plate in the dark, even when the plate is tightly wrapped in black paper. This led the Curies, Pierre and Marie, to the discovery of a new element, radium, which did the same thing but much more powerfully, and which not only glowed in the dark but kept itself several degrees warmer than its surroundings, automatically and constantly. It was the most sensational discovery of modern times. It was not only the first revelation of what we now call atomic energy, but also the first suspicion that the atom has an interior, waiting to be explored. It pointed the way to the new world within the atom that has brought surprise after surprise to twentieth century science.

Within five years it was understood that the atoms of radium are unstable. One after another they explode and in exploding give off three different types of rays called alpha, beta and gamma, the first three letters of the Greek alphabet. They, in turn, cause the generation of both light and heat. The radium atoms are all identical, yet every second a very small proportion of them suddenly breaks up, sending out particles of matter, the alpha-rays, that turned out to be atoms of helium.

Radium also emits electrons as beta-rays and atom vibrations as gamma-rays that are even more penetrating than X-rays.

Whatever the amount of radium in hand, it disintegrates at a steady rate, so steady that it would form a perfect natural clock, for in every 1600 years half of the atoms disappear and half remain. The production of rays is thus reduced to one-half every 1600 years.

Later many other such radio-active elements were discovered, each with a characteristic half-life, some of which are measured in thousands of millions of years, some in millionths of a second, others in hours, days or a few short years. No-one knows why some atoms of radium are destined to explode today while others that are identical so far as we know, will last for centuries. It is a matter of chance, like winning a lottery.

It was the study of natural radio-activity that paved the way to devising artificial radio-activity, that is, methods of forcing atoms to disintegrate and yield up their energy. It took almost fifty years. In the course of those studies much was learned about the ultimate particles that constitute matter and the energy that is associated with those particles. The story ends today with the giant cyclotrons that create such particles. But to tell that story it is necessary here to start afresh with several other aspects of the problem, especially the nature of electricity and of light vibrations, which weave into the story later.

In 1895, just one year before Becquerel in Paris discovered radio-activity, Professor Roentgen at Würzburg, Germany, discovered, quite by accident, that when a current of electricity is passed through a tube that has been pumped out to a high vacuum, one of the electric terminals generates invisible rays that go outward in straight lines. Unlike light, these rays can penetrate not only through black paper but through almost all solid objects. Because of their unknown character they were called X-rays.

Slowly it was proved that they were indeed exactly the same type of etherwaves as light but much shorter in wave-length. The waves of visible light are about 0.4 thousandths of a millimeter in length. X-rays are about 0.1 millionths of a millimeter. Still later it was found that the gamma rays from radium are of the same type but still shorter — only about 0.01 millionths of a millimeter. It is the shortness of the waves that enables them to penetrate through solid objects, much as small waves or ripples entering a harbour pass between rows of stakes or piles that stop the larger waves. Their use in medicine is now well known and depends on their going more easily through soft tissues than through solid bone, so that they show shadows of bones and other solid objects in their path.

But the origin of the X-rays and how they are formed in the electric discharge tube was not understood for many years. To explain them required a knowledge of the nature of electricity that did not exist at the beginning of the century. Electricity had been used for a long time. Batteries, motors, electric lights and even telephones were in common use. How electricity acts was well known; what electricity is was a mystery.

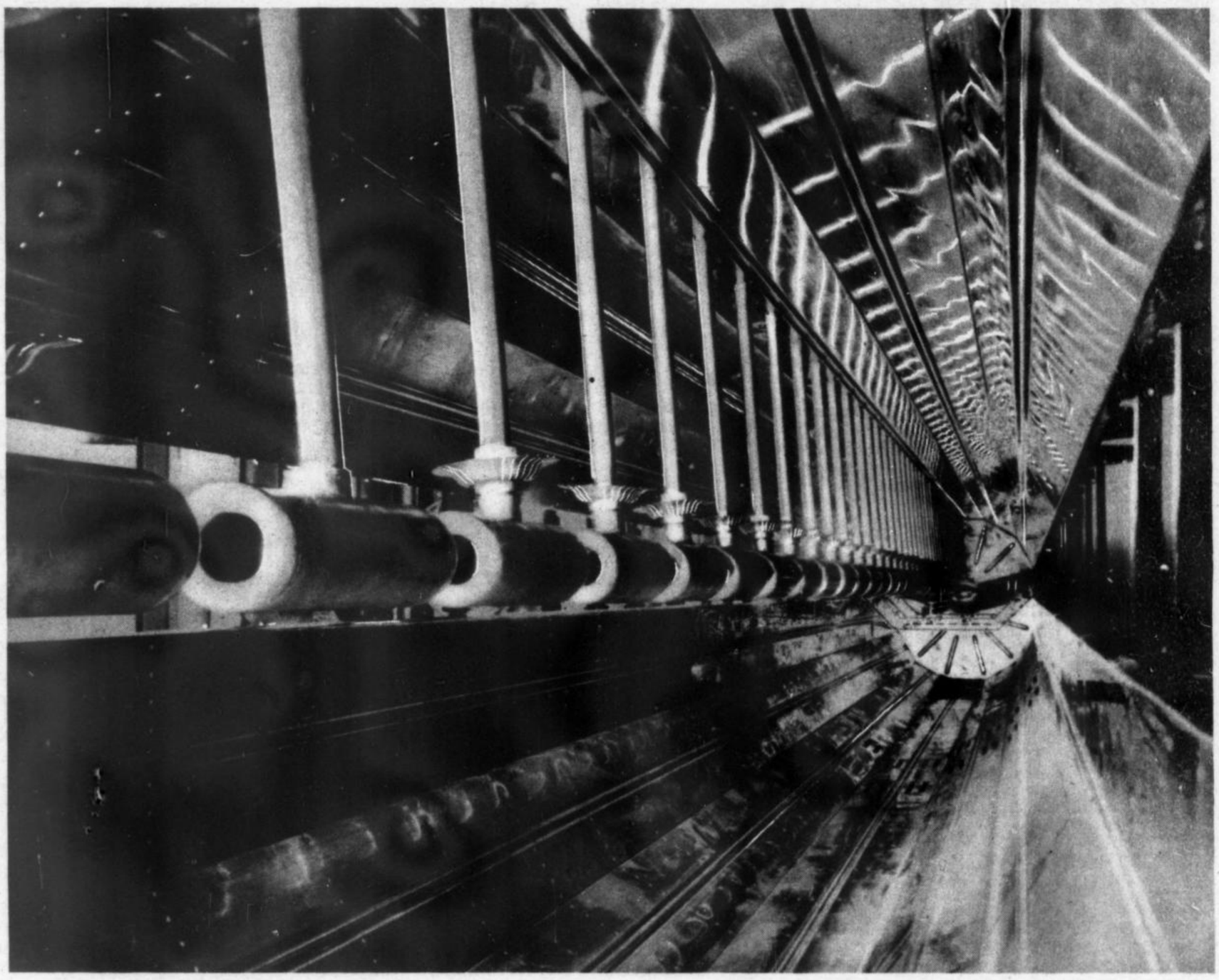
It was Prof. R.A. Millikan at the University of Chicago in the U.S.A. who gave the final answer in 1909. Searching for the smallest quantity of electricity that would still show electrical qualities, he used not the usual electric current but the static form, the charge on a small particle of matter that causes it to attract or repel other charged particles. In his final experiment he used a microscopic droplet of oil which, by itself, fell slowly downwards through the air of his experimental vessel. Then he electrified it to the least possible degree and held it suspended, without falling, by an opposing electric force.

He found that there was a minimum charge and, what is more, all larger charges on the oil-drop were exact multiples of the minimum. It was a simple proof that electricity is not a "continuous fluid" but is itself composed of very small pieces, all alike. They are now called electrons. Just as matter is composed of atoms, so electricity is composed of electrons.

That they are truly particles was proved by measuring the force needed to deflect them from their straight path when a stream of them passes at high speed through a vacuum tube. The mass proved uniform too and is equal to about half of a thousandth of the mass of the lightest known atom, that of hydrogen. It was the first particle to be discovered that is smaller and lighter than an atom. It is indeed incredibly small, for the electric current that passes through a 100-watt electric light bulb in a single second is composed of 10 million million million electrons — ten followed by 18 zeros!

Here was another revelation, ten years after the discovery of radium, which opened another window on the new world of extremely small things. But the electron was at once accepted everywhere as a perfect explanation of all electrical phenomena. These tiny electrons are far smaller than atoms and can pass readily among and through them in a wire, for instance, and thus form a current. A battery of any kind merely pumps electrons into the battery pole that is called negative, and a dynamo is a machine to do the same.

The discovery of the electron also provided the explanation for the origin of the mysterious, penetrating X-rays. When a stream of electrons, an electric current, passes through a wire, it gives (Cont'd on next page)



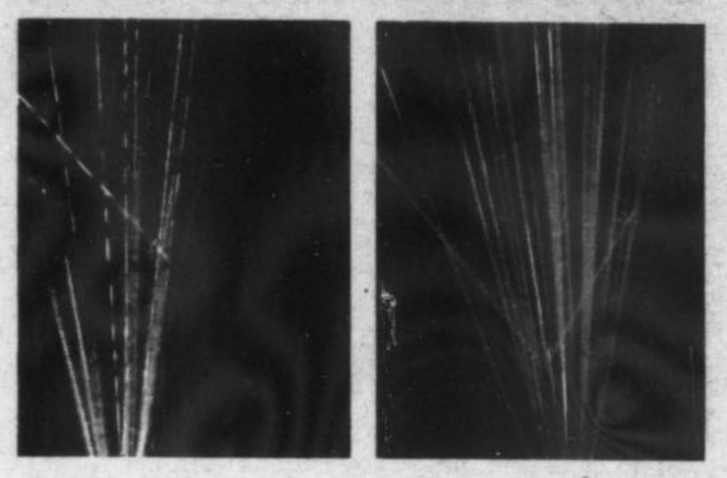
The simplest method of accelerating electronic or nuclear particles is to allow them to stream through successive charged electrostatic plates each of which adds many hundreds of volts to the energy and the speed of the particle. The photograph shows the interior of such a "linear accelerator" at the Radiation Laboratory, University of California. The particles pass through tubes on left.

FIRST STEPS IN OPENING UP THE ATOM

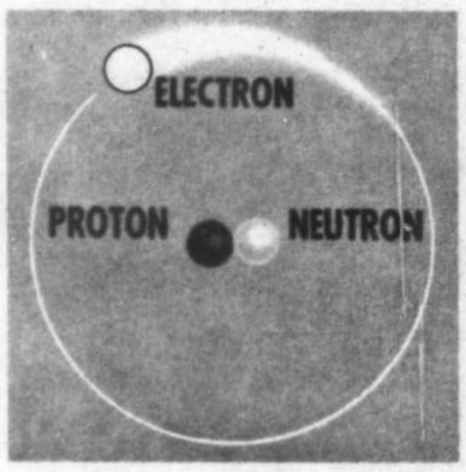
(Continued from previous page)

up some of its energy to heat the wire. Electric lights, heaters and pressing irons depend on this fact. But when electrons pass through a glass tube that has been partially evacuated, they collide with the molecules in the remaining air to make the gas glow. If the vacuum is very high so that the electrons cross through the tube at high speed, they collide with the solid wall opposite. And when on that spot there is a metal plate to form a target for the electrons to hit, their high-speed collisions set up very rapid ether vibrations — the X-rays — somewhat as hitting an anvil with a hammer sets up sound waves. Now the various new discoveries began to fit together to give understanding.

Let us return now to the three types of rays that are automatically generated by the atoms of radium. The discovery and identification of the electron at once explained the beta-rays and the gamma-rays too. For it was soon found that the beta-rays are nothing but electrons, streaming naturally in all directions from every bit of radium, while the gamma-rays, known to be like X-rays, are produced partly as by-products when the high-speed electrons in the beta rays bombard the radium itself.



In the photograph on the left, alpha particles are shown streaming through a cloud chamber. One has hit a hydrogen nucleus, and since the alpha particle has a mass four times as great, its path is hardly affected at all. But the light hydrogen nucleus is knocked out of the way towards the left. In the right hand picture, an alpha particle collides with a helium nucleus. These particles are identical in mass, and it can be seen how they share the energy of the impact and the fly off with equal deflections.



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The atom of heavy hydrogen 0.02 per cent of which is found in all natural hydrogen and all natural water. Heavy hydrogen, or deuterium as it is called, has a neutron as well as a proton at its nucleus.

★

This explained part of the mystery of radium but it also brought a new surprise. It meant that there must be a store of electrons deep within the atom of radium. Thus the atom cannot be a hard, solid, ultimate particle but must be a complicated structure composed partly of electrons and with enough energy packed inside to propel the electrons outwards in the form of beta-rays almost at the velocity of light.

But it was the investigations of alpha-rays from radium that finally revealed the structure of the atom. The alpha-rays are not electrons nor are they ether vibrations. They are composed of relatively large particles. Measurement of the mass of the particles by the same method that was used with electrons — namely by measuring the force necessary to bend them from their swift straight path of flight — showed that they are of atomic size, thousands of times heavier than an electron.

They turned out to be, in fact, atoms of the gas called helium. But not normal atoms, for each of them had two charges of positive electricity. In other words they lack two electrons — since an electron is the unit charge of electricity and is called "negative" merely by an error of naming in the early days when no-one knew what an electric charge was. When the alpha particles strike matter they quickly pick up two stray electrons and become true atoms of helium.

Since the atom of radium must therefore contain both electrons and helium atoms, and ejects both of them at very high speed, the radium atom began to appear complicated indeed. The next step was the series of researches by Sir Ernest Rutherford and his associates in England, in which he allowed a very thin beam of alpha particles from radium to strike a thin sheet of gold. Some of them passed straight through the solid metal ; many changed their line of flight and were deflected from their original direction by some form of elastic impact. A few of them were reflected almost straight back to the direction from which they had come. When Rutherford measured the number of helium atoms that were reflected in various directions, he was forced to the astonishing conclusion that most of the helium atoms went through the metal sheet as easily as if it were not there, but a very small number hit a solid obstacle that repelled them.

The only explanation is that the sheet of solid gold is not solid at all from the point of view of a very small projectile like the alpha particle. The gold atoms are nearly empty. Through this emptiness of the gold atoms the alpha particles penetrate quite easily. But there are some spots in the gold atoms that are solid and impenetrable. This conception of the atom of gold was new but the facts could not be explained at all if the gold sheet were made of solid atoms all in contact and side by side. So what was it that the alpha particles hit? Rutherford called it the nucleus, a very small and very hard centre where all the matter is concentrated and from which the alpha particles bounce. Unless the nucleus is hit, the alpha particles easily go through the gold atoms.

The result is a wholly new picture of the atom. At its centre is a small nucleus. At a considerable distance from the nucleus are electrons distributed in orbits much like the planets around the sun. In fact, the analogy of the solar system is a good one, with the atom nucleus as the sun at the centre, and electrons circulating far away.

★

The collision of an electron with a positron neutralizes their charges, annihilates their mass and converts it into a strong burst of gamma rays.

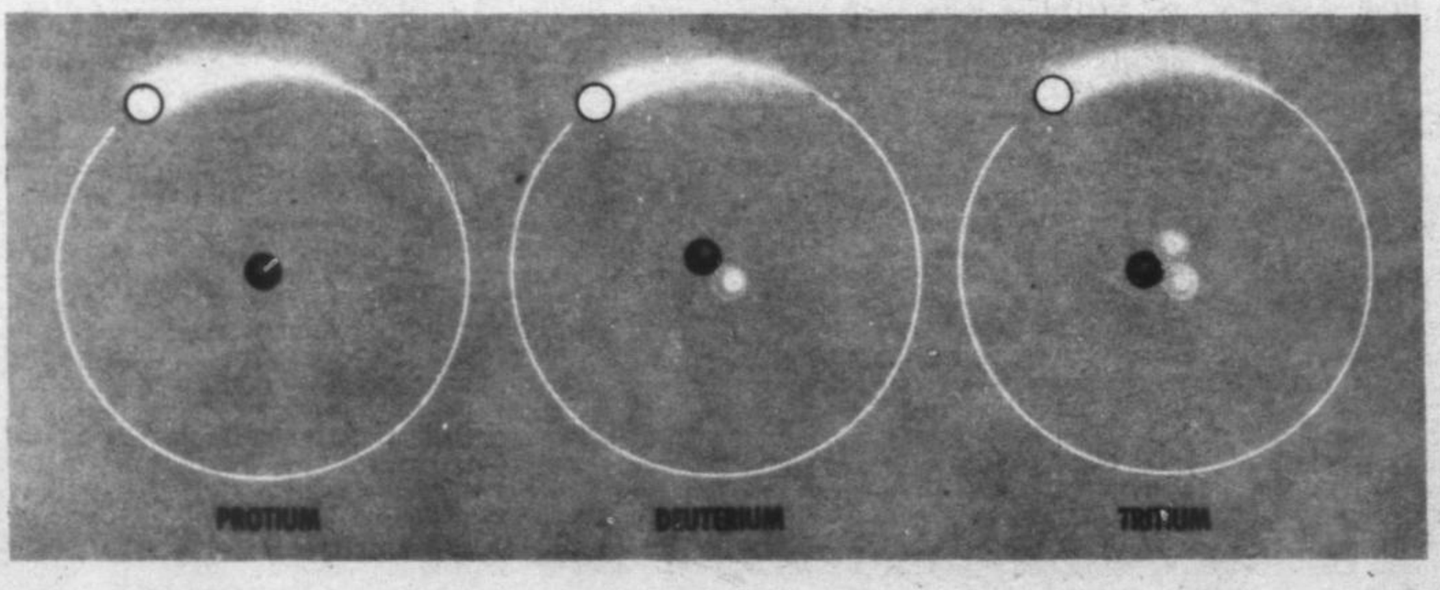
★

But what is hard to realize is that the nucleus is so very small. Its diameter is only 1/10,000th of the diameter of the atom. Thus the diameter of the atom is 10,000 times that of the nucleus. If the nucleus were as large as a hazel-nut the atom would measure 2/3 of a mile across. Yet in that small central nucleus is all the "matter".

It is from the nucleus of the radium atom that the alpha particles are ejected, and the beta rays too. It was at once obvious that the nucleus is not only very concentrated in matter but in energy also. As so often happens in scientific research, the exploration of the atom has only deepened the mystery. Now the problem becomes one of exploring the nucleus.

In considering the structure of the nucleus it should be noted first that, electrically speaking, it is "positively charged". This means, of course,

All the three isotopes of hydrogen have one proton and one electron. They differ only in the number of neutrons in the nucleus. Protium (ordinary hydrogen) has none, deuterium (heavy hydrogen) has one, and tritium (extra heavy hydrogen) has two. In these diagrams the orbit of the electron is much too close to the nucleus. If it were drawn to scale and the nucleus were this big, the electron orbit would be at least 300 feet away.



Some Definitions

★ ALPHA-RAY : One of the three types of rays emitted by the radio-active elements. It is the nucleus of a helium atom, composed of two protons and two neutrons, with a net positive charge of two.

★ ATOM : The unit of chemical composition; the smallest particle of a chemical element capable of independent existence. Atoms are chemically combined in various arrangements to form the molecules of chemical compounds.

★ BETA-RAY : Penetrating ray, composed of electrons, ejected from radio-active atoms at velocities sometimes almost equal to the velocity of light.

★ CYCLOTRON : A device or machine in which electrically charged nuclear particles, such as protons, are forced to move in a horizontal spiral path between the poles of a powerful electromagnet and to receive an additional electrical impulse at each passage around so that they gradually acquire high speed and emerge as energetic nuclear projectiles.

★ DEUTERON : A nuclear particle composed of one proton and one neutron which forms the nucleus of the atom of deuterium or "heavy hydrogen".

★ ELECTRON : The fundamental particle of electricity.

★ ELECTRON-VOLT : The unit of energy in the motions and transformations of electrons, photons and nuclear particles. It is the energy acquired by an electron when it is propelled by an applied voltage of one volt.

★ GAMMA-RAYS : Extremely penetrating rays from radio-active atoms, composed essentially of vibratory waves like X-rays but with waves less than 1/1000th of the length of X-rays.

★ HALF-LIFE : The period of time required for any quantity of a radio-active element to be reduced to half the original quantity by the gradual disintegration of its atoms.

★ ISOTOPES : Different varieties of atoms of a single chemical element; they have the same number of electrons at the surface, therefore the same chemical properties, but the composition of their nuclei is different in the number of neutrons, so that different isotopes of an element differ in the weight of their atoms. Hydrogen and deuterium are examples.

★ MESON : A short-lived particle, either positive or negative, and intermediate in mass between an electron and a proton which was discovered in cosmic rays and is now produced in the proton-synchrotron.

★ MOLECULE : The smallest particle of any substance or chemical compound that is capable of independent existence. Molecules are arranged side-by-side in crystals, near each other at random in liquids, quite separated from each other in gases.

★ NUCLEUS : The dense core at the centre of all atoms, with less than 1/10,000th the diameter of the atom but containing all its mass in the form of one or many protons and neutrons closely packed together.

★ NEUTRINO : A hypothetical particle, not yet actually observed, but believed to be formed when a neutron disintegrates into a proton and an electron and also in certain collisions of cosmic rays, to account for the observed energy. They have no electric charge and practically no mass.

★ NEUTRON : One of the fundamental components of all atomic nuclei (except that of hydrogen). It has practically the same weight as the proton but carries no electric charge.

★ PHOTON : The unit quantity of the energy of light and similar wave-vibrations; it has some aspects of a particle of energy with almost zero mass but can on collision with an atom break up into a positive and a negative electron.

★ POSITRON : Like the electron but is positively charged instead of negatively.

★ PROTON : One of the basic components of all atomic nuclei; it carries a single positive charge. It is also the nucleus of the hydrogen atom.

★ PROTON-SYNCHROTRON : The most powerful type of accelerator for nuclear projectiles which operates on the frequency-modulation principle.

★ RADIUM : One of the chemical elements, discovered in 1898, with the unique property of giving off alpha, beta and gamma-rays from the nuclei of its atoms, and thus of changing into a series of other elements and eventually into lead.

★ SYNCHROTRON : A machine suitable for the acceleration of electrons to speeds near that of light and to an energy level which increases their mass (according to the Einstein principle) so that the frequency of the propelling electrical oscillation must be modulated.

★ V-PARTICLE : The most recent of the elementary particles discovered in cosmic rays, produced in the high-energy accelerators. Its exact nature is still unknown.

★ X-RAYS : The rays, essentially wave-vibrations, produced when electrons in a vacuum tube are hurled under high voltage against a metallic cathode. They are the same type of wave-motion as ordinary light but their waves are only 1/1000th the length of visible light waves. They are invisible but can penetrate through several centimeters (or inches) of matter, depending on the voltage with which they are produced.

The use of radium in medical treatments, especially for cancer, is well established, but limited and expensive. The cyclotron has led to the manufacture of artificially radio-active isotopes of a long list of chemical elements. The photograph shows a patient at the Brookhaven National Laboratory, Upton, N.Y. in the United States, which has the first hospital ever to be devoted exclusively to the medical effects and uses of atomic rays. A Geiger counter, aimed at 'X' marked on patient's throat, is used to measure quantity of radio-active iodine remaining in thyroid gland after a patient has been given an "atomic cocktail" to drink.

only that electrons are missing. But the whole atom is neutral, electrically. Thus the positive charge on the nucleus is matched by the negative electrons forming the atom's exterior layers.

It was mentioned above that the alpha particle is a helium atom with two positive charges. That can now be better said. The alpha particle is merely the nucleus of the helium atom, without the two external electrons that characterize the atom of helium. Thus the radium nucleus merely ejects a helium nucleus in its automatic explosion.

It is therefore easy to suspect that the helium nucleus is one of the inherent components of the nuclei of other atoms. But this is not quite the case. The helium nucleus is itself complex. Space does not permit a detailed description of all the researches which led to the present conception of the atomic nucleus. But the conclusion is that one of the basic components of all atomic nuclei is the nucleus of hydrogen not of helium.

Hydrogen is the lightest and simplest of atoms, with only one electron at its surface and one positive charge on its nucleus. Its weight is also a unit, for the weights of all larger atoms are simple multiples of the weight of the hydrogen atom. It is the hydrogen nucleus, smallest and simplest of all, that is the chief building stone. All the larger atomic nuclei are built, at least in part, from this unit. For this reason it deserves a special name : it is the proton.

But it is not the only building stone. One more particle must be introduced before the list of major nuclear components is complete. That is the neutron. It was the last to be discovered because, oddly enough, it is not electrically charged and therefore is very hard to detect. It is of the same weight as the proton but it is not positively charged. It must therefore somehow contain an electron within it to make it neutral. That one electron makes the only difference between a proton and a neutron.

The word "within" is important here. A positive proton can be balanced by a negative electron circulating in an orbit around it, like a planet around the sun. This is the hydrogen atom. But, if, somehow, the electron enters into the proton, as if the sun had swallowed its planet, the result is a neutron. Conversely, knocking an electron out of a neutron converts it into a proton. But such interference with the structure of protons and neutrons is not easy. They are practically untouchable except by the powerful cyclotrons that are described in another article of this series.

The discovery of the neutron by Prof. Chadwick in England came late—not until 1934. It proved to be the key to many puzzles. It explained at once what the alpha particle is as well as heavy water, and gave a clear understanding of isotopes, as will be shown in the next paragraph. It also made possible the transformation of one type of atom into another and thus paved the way not only for transmutation but for the actual creation of new chemical elements.

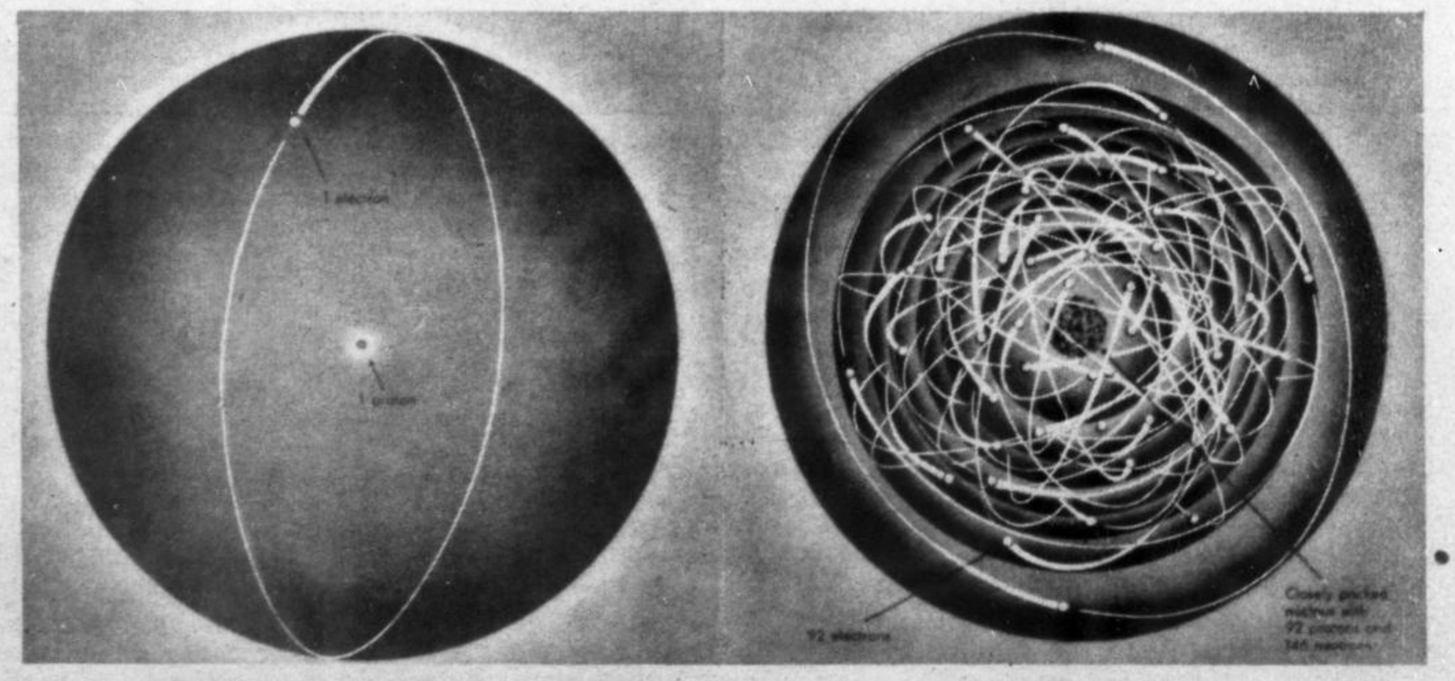
Heavy water, much in the scientific news in recent years, is easy to understand. Water is, of course, the oxide of hydrogen and heavy water is merely the oxide of heavy hydrogen. The hydrogen atom as has been said, is merely a proton with an electron circulating in an orbit about it. The weight of this atom is essentially that of one proton. But Prof. Urey in the United States discovered a form of hydrogen whose atom weighs twice as much, yet in all other properties is identical with ordinary hydrogen. In fact, there is a small proportion of this heavy hydrogen in all natural hydrogen gas and in all natural water. The explanation came with the neutron, for the nucleus of this type of hydrogen is a particle composed of one proton and one neutron, intimately and firmly joined. It thus weighs twice the normal weight, but has only one positive charge on the nucleus and therefore only one electron at the surface of the atom. It is called deuterium and its nucleus is a deuteron.

The two different forms of hydrogen, chemically alike, yet different in their nuclear structure, are known as isotopes. As nuclear research advanced in the past ten years it became possible not only to discover many natural isotopes of the chemical elements but to create many hundreds more that do not exist in nature. In some of them the various unions of protons and neutrons are not entirely stable so that they gradually break up with the emission of energy in rays in exactly the same way that radium disintegrates naturally. These artificial radio-active isotopes have become extremely useful in medicine, agriculture and industry and are the topic of a later article in this series.

The alpha particle that is ejected in the automatic explosion of the radium atom is also explained by the neutron. The alpha particle has two positive charges and when it adds two electrons it forms an atom of helium. But the weight of this atom, and therefore of its nucleus, is four times the weight of a proton. The explanation is obviously that the alpha particle is composed of two protons and two neutrons. This gives it a weight of four units and two positive charges.

With this explanation of the mysterious alpha particle the list of well-known fundamental particles of matter is complete. Within the atom but at the surface are the electrons, responsible for its chemical properties. Deep within the atom is the nucleus, thousands of times smaller than the atom itself but containing all its "matter". It is composed of protons and neutrons and must somehow contain electrons too. In various combinations the protons, neutrons and electrons make up the nuclei of all atoms. In the radio-active atoms, such as radium, the nucleus is unstable and occasionally ejects one or another of its constituents and thus changes into a different isotope or, indeed, into a different chemical element. So the new facts and conceptions begin to fit into a single picture which was inconceivable fifty years ago but which now reveals a wholly new world within the atom.

But great underlying problems remain. What holds the nucleus together? Is the proton really the ultimate particle, or does it have an internal structure too? How does an electron get into it to make a neutron? Whence comes all the energy that propels the rays at such high speeds? All such questions were insoluble with the older tools of science. They have been successfully attacked in recent years with the great cyclotrons that are described in the third article of this series. But that would not have been possible had not valuable hints come literally from the sky. Cosmic rays brought the clues to these mysteries and paved the way for the cyclotrons. The following article therefore takes a look at these very high speed particles that bombard the earth from outer space and come from no-one knows where.



These diagrams, in a study of atomic extremes, show the structure of the lightest atom, hydrogen, contrasted with the heaviest atom, uranium. Hydrogen has only one proton in the nucleus and one electron spinning in an external orbit. Uranium has 92 protons and 146 neutrons crowded together in the nucleus, and 92 external electrons vibrating in complex orbits. In both diagrams the nucleus is much magnified. Its diameter is actually only 1/10,000th of the atom's diameter and thus it would only be an invisible speck at the atomic centre.

❷ THE HAIL OF COSMIC RAYS FROM OUTER SPACE

A BALL lying still on a table is harmless; the same ball flying through the air can be dangerous and cause pain. The difference is the energy of the ball's motion. Is it the ball that hurts when it strikes, or is it the energy?

What would be the effect of throwing a package of energy alone, with no ball? It cannot ordinarily be done because energy is normally carried by pieces or particles of "matter". In the case of molecules and atoms it is usually the energy of motion, even when it is felt as heat. In the case of protons and electrons it may be electrical energy.

But in the case of the particles that are smaller than the atomic nucleus, whether inside it or free in space, energy is their outstanding property. Only in motion or through some form of energetic action can any of the particles of nuclear size be detected and studied. It is thus in the form of "rays" that these exceedingly small particles come to man's attention. In nuclear research the subject of study is always a combination of matter-and-energy in which the two are so closely related that one may even turn into the other.

The most energetic particle produced naturally on earth is the alpha ray from radium, which is a helium nucleus ejected at perhaps one tenth of the velocity of light. How it gets that speed and energy from within the close quarters of the radium nucleus is still a mystery. But if such concentration of energy is rarely found on earth, outer space, the "empty" space beyond the earth's atmosphere, bristles with it. The study of these "cosmic rays" is one of the most intricate and adventurous of all modern researches and can merely be sketched in a brief article.

It began during the opening years of this century when the British Professor C.T.R. Wilson first suspected that the gradual leakage of static electricity from his well insulated laboratory apparatus was due to some unknown penetrating radiation, like X-rays perhaps, originating outside the earth.

The Swiss scientist A. Gockel, testing this idea in a balloon, found in 1909 that the effect was in fact stronger at an altitude of 2½ miles (4,500 metres). In the next year the Austrian V.F. Hess confirmed this discovery by ascending still higher to 5,200 metres (3¼ miles), and gave the rays their present name: cosmic. In 1913 the German Kolhorster reached a height of six miles (9,000 metres) and found that at that height the rays were 30 times as intense as at sea-level.

From where do they come—the Milky Way? Nobody yet knows

Whence do they come? An easy guess is that their source is the sun. But they are just as intense at night as by day, even though at night the entire great mass of the earth is in their path — so they do not come from the sun. From the stars of our own galaxy, the Milky Way? That is possible, perhaps probable. Or they may be produced by collisions or explosions of individual elementary particles in the emptiness of space itself. At present no-one knows.

What is known is that the energy that constantly reaches the earth in this form is at least as great as the energy of all the light from all the stars — except the sun. We live in a constant hail of cosmic rays. Each human body is pierced more than twenty times a second by these rays — which, fortunately, are harmless.

What is astonishing about them is their enormous energy. They are certainly particles, most of them protons, some of them the more complex nuclei of helium atoms, with a small proportion of the larger nuclei of heavy atoms. But they come to earth at speeds very close to the velocity of light and with energies that are measured in many thousands of millions of electron volts — or even millions of millions.

The electron-volt is the unit of energy used for such individual particles. Technically, it is the energy acquired by one electron when it is accelerated by a propelling voltage of one volt. To knock an electron from an atom of oxygen in the air requires about 30 electron-volts. Alpha-rays from radium carry 4 to 10 million electron-volts.

In the universe of the infinitely tiny everything is astronomical

But for a cosmic ray to enter the earth's atmosphere near the equator, in defiance of the earth's magnetism, requires an energy of at least 20 thousand million electron-volts. These are the feeblest of them. The most energetic yet found have an energy of a 100,000 million times a million electron-volts. These are energies far beyond any other earthly experience.

How this energy is acquired somewhere in the depths of space is quite unknown. Even if, for instance, an atom of helium were completely destroyed, annihilated, and changed into energy in accord with the Einstein theory, that energy would amount to only 4,000 million electron-volts. Another assumption, made by the Italian Professor Fermi, is that the energy is gradually built up by the passage of the particle through magnetic clouds of matter in outer space which would accelerate a particle as a tennis racquet speeds a flying ball.

But no theory of the source of their energy is adequate; the explanation awaits further investigators. It may well be that the problem will not be solved until the rays can be studied in an interplanetary rocket far out in space or in a laboratory set up on the air-less surface of the moon.

Even more fascinating is the story of what happens when these rays strike the earth's atmosphere and drive downward. Twenty years of investigation with the instruments of modern nuclear physics have produced photographs of their tracks in passing through air and through interposed targets. They have been measured on the tops of mountains, in the depths of mines, under deep water, and high in the stratosphere by balloons and even in rockets. They have revealed more of the nature of matter and of energy than would possibly have been believed even ten years ago. Only the conclusions — as of now — can be told here.

Out in space there may be rays of relatively low energy. But those that move with less than a thousand million electron-volts are deflected by the sun's magnetic field and never get near the earth. Those that do reach our vicinity and have less than 60 thousand million electron-volts are deflected by the earth's magnetic field.

The very energetic particles that drive toward the earth's surface in spite of the magnetic field collide with the atoms in the upper regions of the stratosphere. In such collisions they lose part of the energy and create whole showers of electrons which in turn plunge toward the earth. Such showers covering many square miles of the earth's surface were revealed by extended measurements on high mountains by the French Professor Pierre Auger.

But the showers also contain photons, which are uncharged units of radiation energy, particles of light, so to speak. These can disintegrate into a pair of electrons, one positive and one negative. This already gives us two new particles, not mentioned previously, the photon and the positive electron, which is quite like the usual negative electron, except that it is positively charged. It was first discovered in cosmic rays by the American Dr. Carl D. Anderson in 1942.

But later several other new particles were discovered in these rays. They are known as mesons. They have the charge of an electron, some of them positive, some negative. But they are intermediate in mass between an electron and a proton. One variety has a mass of 276 times that of an electron, another of only 210. Their existence was suggested theoretically by the Japanese mathematician H. Yukawa in 1935 and they were discovered in cosmic rays in 1938.

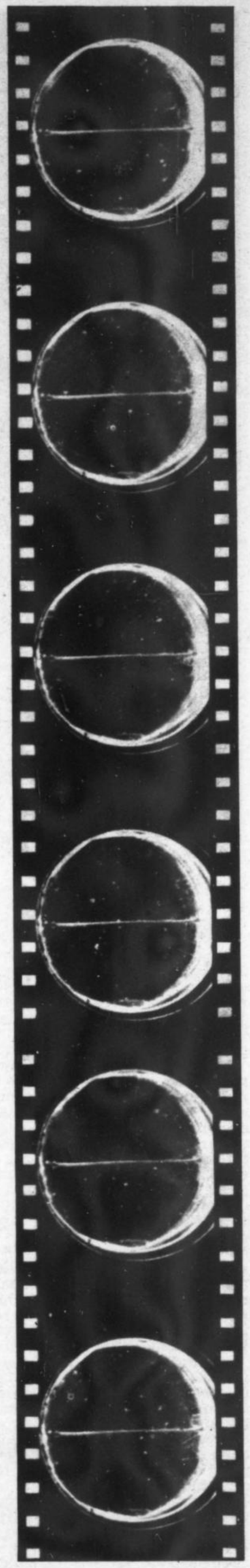
But here is another surprise: the meson is a phantom particle in that it exists for only a few millionths of a second. In spite of their short life they can be detected because, at their high energy, they travel great distances. They seem then to be converted into high speed electrons, and in the process give rise to still another elementary particle, the neutrino.

By now the variety of particles in or produced by the cosmic rays has become too complex for anyone but an expert to comprehend. Present knowledge is in that rapid state of growth when there are more questions than answers. When the maze of particles are themselves understood there will remain the problem of how they are held together in the atomic nucleus, which is now seen to be a very complicated particle indeed.

There is at this moment much discussion as to the role of the mesons in acting as a force binding the others together, hence acting as a sort of glue within the nucleus.

The rays from the sky have thus revealed unsuspected mysteries within the nucleus itself. They are very difficult to study because they arrive uncontrolled from the outer universe and are at their best high in the stratosphere. To study particles of such high energy on earth and in the laboratory requires that the same particles be artificially created and the cosmic rays thus duplicated. This in turn requires endowing them with much more energy than any earthly particles normally possess, literally thousands of millions of electron-volts. To do this is the function of the giant cyclotrons. The story of how it is done is the subject of the next article in this series.

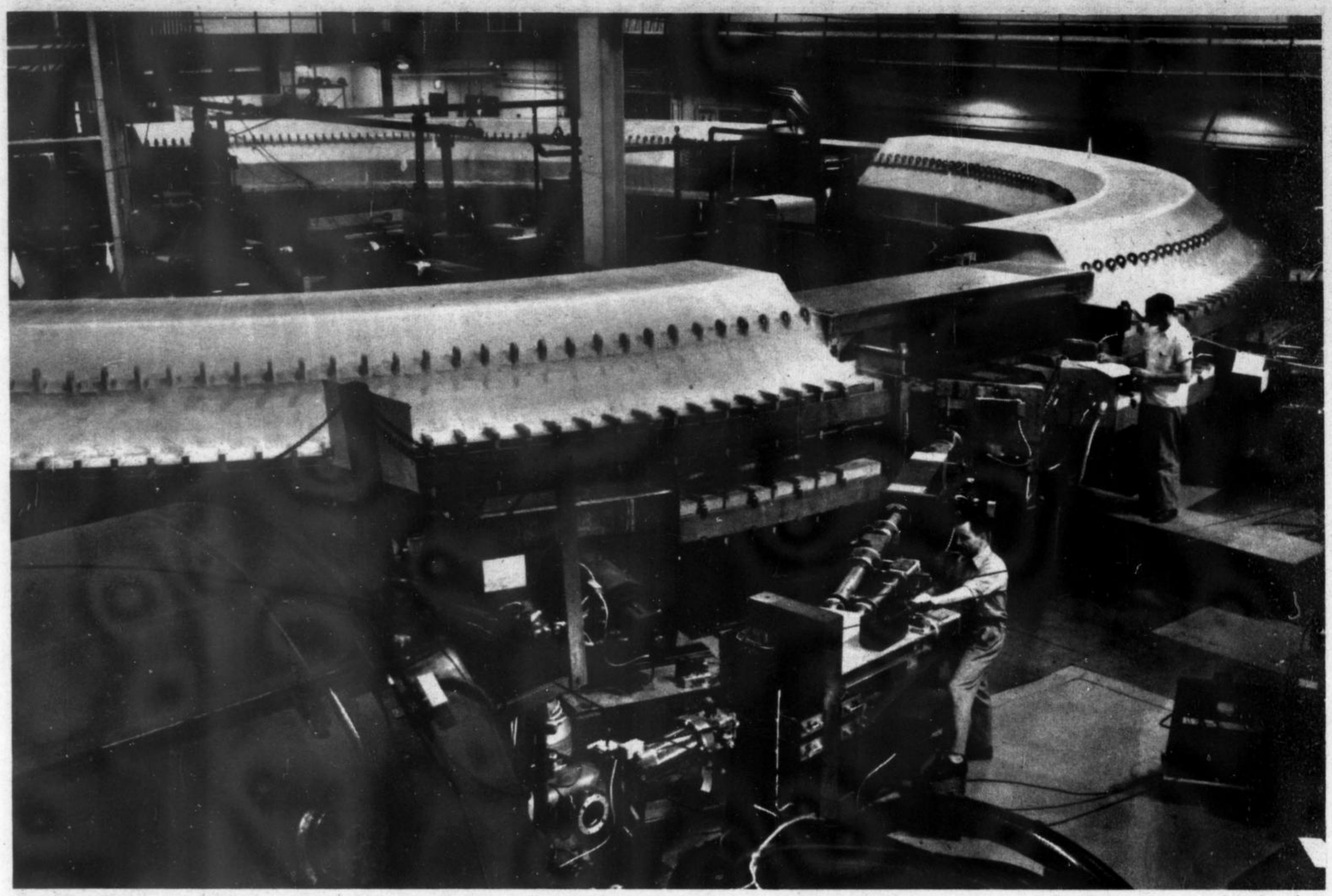
One may note in passing that this one short article has mentioned pioneer cosmic ray researches in Great Britain, Switzerland, Austria, Germany, Italy, France, the USA and Japan. Research is active in this subject in many other lands, for cosmic rays are everywhere. But cyclotrons are expensive and research with them not so widely spread among the nations.



★ ★

Nuclear events (collisions between high energy atomic particles and nuclei) are revealed by the thin white tracks shown in this strip of photographs, made at the Nevis Laboratory, Columbia University, USA Tracks of particles which have been given a high speed in a cyclotron are automatically photographed every ten seconds. Studies of these tracks help scientists to understand more about the particles and how they are held together in the nucleus of the atom. Our front page shows a similar photograph enlarged.

(Photo Copyright "Scientific American").



To learn more about the makeup and nature of the atom nuclei scientists bombard them with high energy particles. These are raised to phenomenal speeds in accelerators such as the Cosmotron (above) at Brookhaven National Laboratory, United States of America, which is at present the largest machine of its kind in the world. The huge "doughnut"-shaped magnet 75 feet in diameter guides the particles in a circular path while they are given a high speed by a succession of electric boosts. In this Cosmotron, the particles circle the magnet 3,000,000 times and travel a total distance of some 138,000 miles in less than a second.

❸ GIANT MACHINES AND MAN-MADE RAYS

THE world within the atom, as revealed by the natural rays from radium and by cosmic rays and briefly sketched in the two preceding articles, is almost incredible from the ordinary human point of view. This is not merely because it is so complex but also because the basic particles seem to have no relation to either matter or energy as we commonly know them. The appeal to curiosity and the desire to explore further is almost irresistible.

The nucleus of the atom contains all the "matter", yet is so small that it occupies only a thousandth of a millionth of a millionth of the space within the atom. In that case its density (that is, its weight per cubic inch) must be a thousand times a million times a million times that of ordinary materials. As a matter of fact, researches with the cyclotron, such as will be described below, now indicate that the nucleus itself is not at all a solid mass but has a still denser core at its centre. Whatever that core is made of, it is so dense that a lump of it as large as a drop of water would weigh two million tons.

But that is only half of the astonishing situation. Energy is similarly concentrated. Within that exceedingly minute volume of the atomic nucleus there are forces that hold the mass together. The earth itself is held together by gravity but the force within the nucleus must be so much larger than gravity that there is no word to express it. The force of gravity would have to be multiplied by a number that contains the figure 1 followed by 37 zeros :

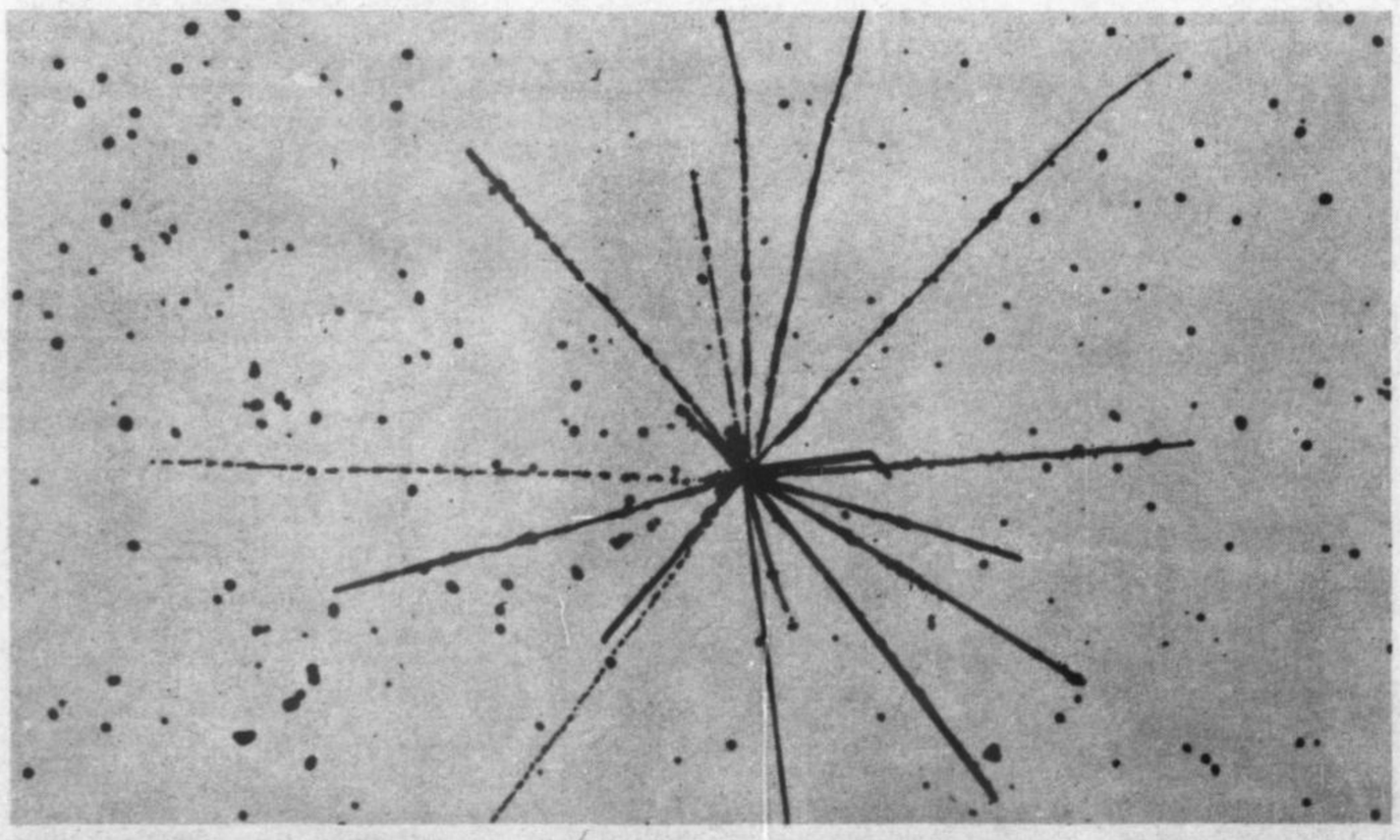
10,000,000,000,000,000,000,000, 000,000,000,000,000.

Gravity holds the planets in their courses and the stars in the sky—but has no place in the nucleus.

The whole atom is itself held together by electrical forces, since the positive protons at the centre attract and hold the negative electrons at the surface. But within the nucleus are protons and neutrons which cannot be held together electrically because the electric force between them would not attract but repel them from each other.

So the binding force within the nucleus is of a new and unknown form. It is complicated and depends on the velocity of the nuclear particles and even on their spinning motion or rotation. On the other hand the force, whatever it is, does not depend on the electrical charges, for neutrons and protons seem to attract each other to precisely the same degree that they attract their own kind of particle. This is the present mystery of the nucleus and therefore of the atom and thus of matter and energy in general.

Certainly this is the basic mystery of the universe and one with which science cannot be content. But to solve it requires methods and instruments never before conceived. What is needed is a sort of nuclear microscope which would permit gazing at the crowded infinitesimal intimacy of protons and neutrons as the astronomer gazes through his colossal telescopes at the infinity of space.



This star-like picture is the "self portrait" of an exploding nucleus of an atom, and is one of the most significant milestones along the road of nuclear research. This nuclear "event" was photographed when a very high energy particle, accelerated in the giant Cosmotron (top of page) hit the nucleus of an atom of the film emulsion and exploded it into 17 particles of different types which flew out to form tracks in a star-shaped pattern. Until this man-made nuclear collision took place the type of nuclear event pictured here had occured only in the action of cosmic rays which, as they bombard the earth's atmosphere, produce the highest energies which atoms have been known to release. (Photographs : Brookhaven National Laboratory, NewYork.)

Atom-smashers in action

BUT light waves are millions of times longer than the size of the nuclear particles. There is no way to probe into the nucleus that does not pry it open or take it apart. To do that requires concentrations of energy just as high as those in the nucleus, and even higher. The successful method is one which fires electrons and protons at the nucleus at velocities very close to that of light and loaded with energy amounting to thousands of millions of electrons-volts. It is for this reason that the devices that serve as atomic or nuclear microscopes are often called "atom-smashers".

It is not difficult to give these tiny projectiles, electrons and protons, energy by giving them speed because their electric charge propels them if they are exposed to a high voltage. This was first done in the tubes for generating very penetrating X-rays. The higher the voltage across the terminals of the tube, the higher was the speed of the electrons and the more penetrating the X-rays produced.

This led to the design of X-ray tubes operating

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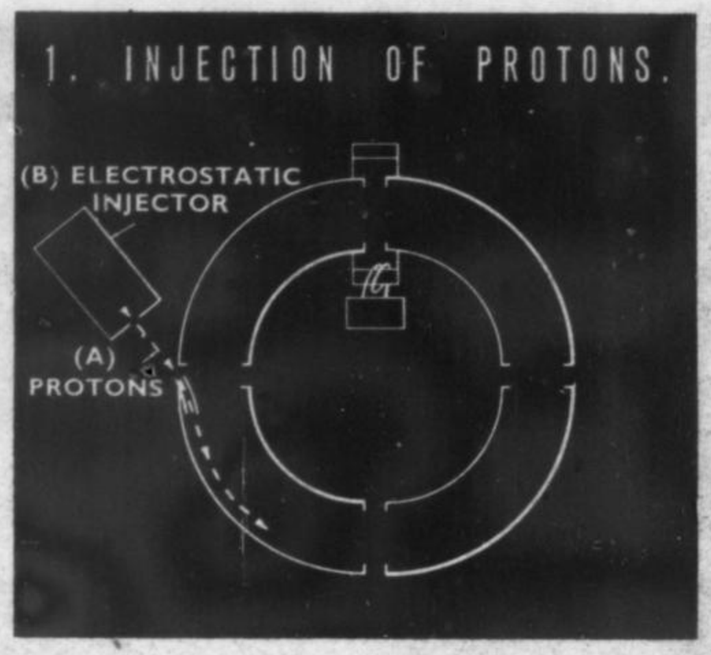
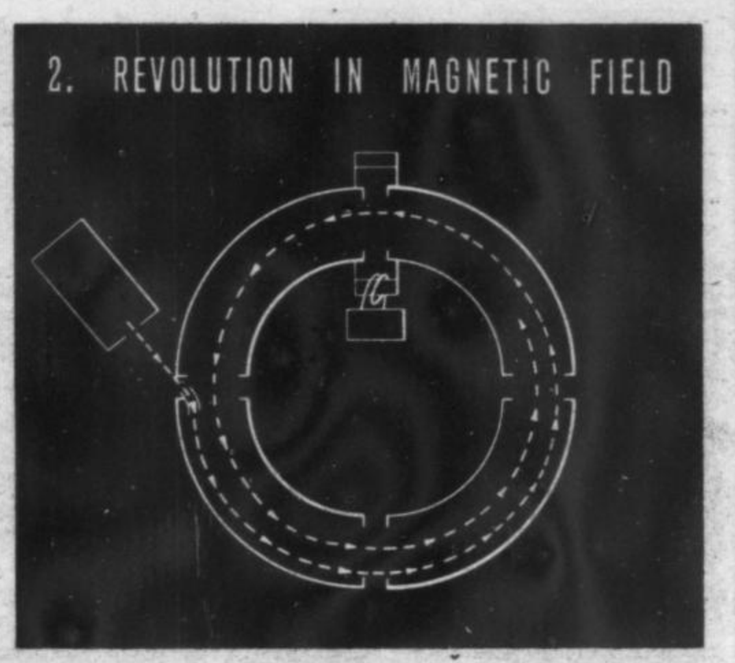
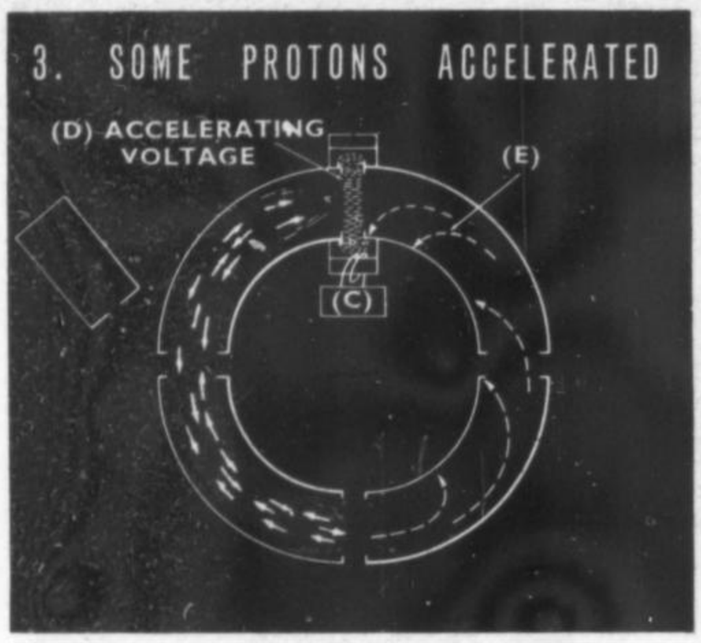
THE COSMOTRON AND HOW IT WORKS



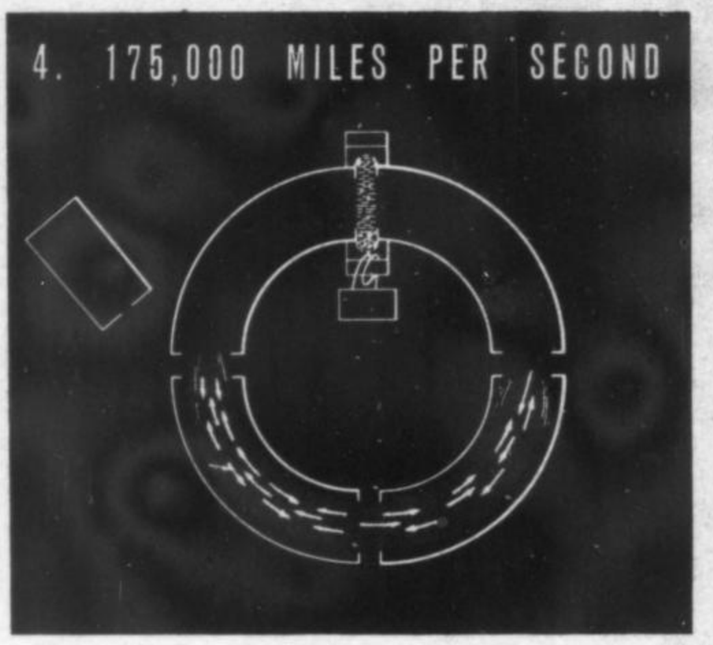
Protons (A) from electrostatic generator (B) are "shot" into the metal vacuum tank of the Cosmotron at an energy totalling 3.6 million electron volts.



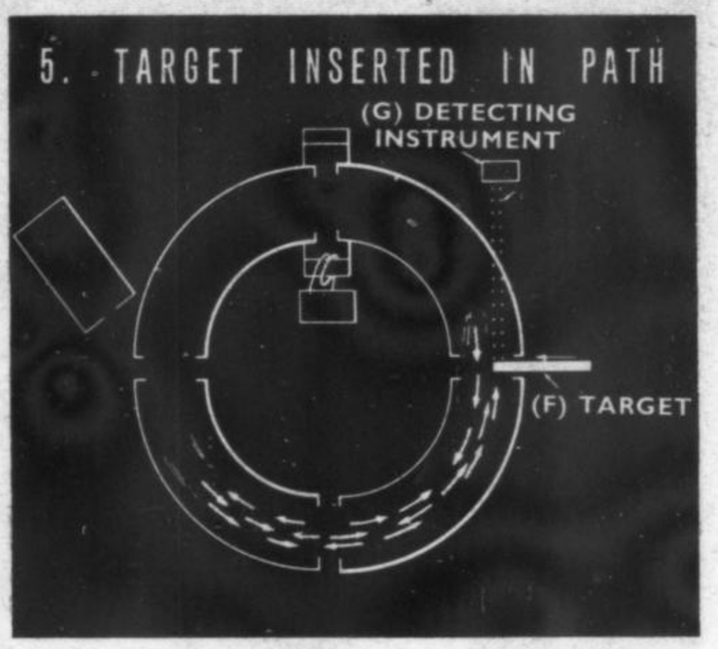
Increasing the magnetic field causes the protons to spiral around Cosmotron (dotted lines). They are now making a total of 350,000 revolutions per second.



An amplifier (C) produces accelerating and decelerating voltage causing about half of the protons to speed up and other half to slow down. Protons that are speeded up by accelerating voltage (D) group together in a sausage shaped bundle and continue to revolve at higher and higher speeds. Slowed down protons (E) strike inside wall and are lost.



The proton bundle is now revolving around the entire vacuum tank at a rate of 4 million times per second (or 175,000 miles per second, 90 per cent of the speed of light). After about 3 million turns (in 0.8 seconds)—the equivalent of four trips around the earth — these protons have acquired the energy of two thousand three hundred million electron-volts.



At this energy the protons hit a target (F) inserted in their path. They collide with the target, and nuclear fragments (such as neutrons) shoot out of the magnet in a straight line. Detecting instruments (G) such as a cloud chamber or geiger counter are used by scientists to study result of collision of these particles with various chemical elements.

(Continued from previous page)

under a million volts. But in order to reach such a voltage, it had to be applied step-wise. As the electron passed down a long tube, it went through a series of electrodes each of which added a few thousand more volts to the pressure and therefore to the speed of the electron.

But a million volts is not enough for penetrating deep into the nucleus and it is not practical to operate such a tube with more than a few million volts. The next step taken was in effect to wind the tube in the form of a spiral by means of a magnetic field. There were, in fact, only two electrodes, formed from a single hollow circular box with a slit across the diameter. This gave two electrodes, each shaped like a capital D, back to back, with a narrow air space between them. When the entire box of two D's was put between the poles of a heavy magnet, then an electron injected at the centre would normally travel in a circular path, around and around.

But when voltage is applied to the D-shaped box, the electron receives a kick each time it passes through half the circle. When it thus goes faster, it would travel in a larger circle because the magnet is less able to turn its path. But it continues its flight, passing repeatedly through each D, thus going ever faster and therefore describing a larger and larger circle. In effect, its path becomes a spiral. In the end, when it has attained an energy of several million electron volts, it reaches the outer edge and passes out through a slit in the side wall at top energy. Then it can be used to generate powerful X-rays or for other experiments.

But the electron is a relatively light projectile. When the heavier proton is similarly whirled to a high velocity, its energy content should become sufficient to counteract the binding forces in any nucleus that it later hits. This was the principle of the first cyclotron made by Dr. Ernest O. Lawrence, of the University of California, who received the Nobel Prize for Physics in 1940 for this achievement. Many refinements have since been added to the cyclotron and in its present development it is called a proton-synchrotron.

The largest proton-synchrotron now in operation is at the Brookhaven National Laboratory, operated by the Associated Universities, Inc., under contract with the United States Atomic Energy Commission. From an auxiliary generator it injects protons which carry 3.6 million electron-volts. These protons enter the great proton-synchrotron in bursts at intervals of five seconds.

In less than a second they go around inside the large circular magnet about 3 million times and by then have reached an energy of 2,300 million electron-volts. The magnet has a diameter of 75 feet, so that 3 million circuits of the path amount to a total distance of 130,000 miles, which is about four times the distance around the earth and half the distance between the earth and the moon. At that energy, they are ready for use.

A target piece, consisting of an extremely thin sheet of metal, is interposed in the path. In the violent collisions of these high energy protons with the nuclei of the metal the atomic nucleus is shattered. The resulting fragments emerge from the cyclotron and can be photographed in what is called a cloud chamber with results such as are shown on the cover of this issue.

It looks like a picture of a catastrophe or like a hurricane among the stars, but each white streak is the path of one of the many types of rays or of nuclear fragments. Each can be identified as one of the constituents of the atomic nucleus. A careful study of the photograph will show that there are occasionally sharp breaks in the path and some points where a path seems to cause another explosion with two or three, or even four particles darting out at various angles. This is indeed another explosion, similar to those that occur in the cosmic rays. In a sense, this photograph shows a shower of artificial cosmic rays.

A 'sixth sense' at work

THE photograph on page 9 shows a single such collision, this time made by placing a photographic plate directly in the path of the rays. One of the high-energy particles from the proton-synchrotron hit the nucleus of an atom in the photographic emulsion in such a way that it exploded into no less than 17 separate particles, which can be counted.

The careful study of photographs such as these two gives the chief evidence of the existence of such short-lived particles as the mesons and the more recently discovered V-particles. Each track must be analyzed for its degree of curvature, its length and intensity, and its effectiveness in producing branching rays. No human sense can detect these particles. The combination of the great proton-synchrotron and the photographic plate is the "sixth-sense", or the nuclear microscope, that reveals these deepest secrets of nature.

It is important, however, to note that the shattering of nuclei is not the only effect of these high-energy particles. In a large number of cases the high-speed particle, whether it is an electron, a proton, a deuteron or an alpha particle, enters the nucleus which it hits and remains combined with it and thus transforms that nucleus to a new architecture which, in turn, makes it an atom of a different element.

In other cases the combination breaks down into two smaller nuclei. Thus the high energy particles of the cyclotron and the proton-synchrotron have been used to create not only new isotopes of well known chemical elements but to create elements that do not exist in nature. The dream of the medieval alchemists, of making gold from mercury and other common metals, has long since come true, has indeed, been far surpassed.

A very common case of this kind is the creation of isotopes of elements whose nuclei are only partially stable and that gradually disintegrate with the emission of rays like those from radium. A long list of artificial radio-active elements has thus become available. Some, like radio-active cobalt, can be used as a source of rays in medical uses, where radio-active cobalt has, in fact, now largely replaced radium because it can be made very cheaply. Indeed the uses of the radio-active isotopes in medicine, agriculture and industry are so varied and valuable that a separate article is devoted to them later in this series.

The proton-synchrotron at Brookhaven has been operating only about a year and its results have not yet been studied sufficiently for general publication. It is expected, however, that with further modifications, protons can with this machine be given energies as high as 3,000 million electron-volts.

This energy, high as it is, is only at the very threshold of the power needed for the study of mesons, neutrinos, and the new V-particle, all of which are still mysterious. In order to produce an adequate stream of artificial mesons, a still higher energy is needed. A proton-synchrotron that can reach 6,000 million electron-volts is at the University of California. It is a colossus in which the magnet weighs 10,000 tons and the power to energize the magnet is nearly 8,000 horsepower (6,000 kilowatts). The United States Atomic Energy Commission has been asked to build a still larger machine impart 15,000 million electron-volts to its proton projectiles.

But the most powerful of all is now being planned for erection at Geneva for the European Council for Nuclear Research. It is to provide 30,000 million electron-volts. A new principle of keeping the rays in the desired path will greatly reduce the weight of iron needed in the magnet so that this major item of cost will be much reduced. As now planned the Geneva proton-synchrotron will have a relatively thin or narrow magnet but the diameter of the circle will be about 1000 feet. No building would be big enough to house it; it will be buried in a large circular underground trench. Details are discussed in the next article of this series.

C.E.R.N.

CONSEIL EUROPEEN POUR LA RECHERCHE NUCLÉAIRE

SYMBOL OF EUROPEAN COLLABORATION FOR NUCLEAR RESEARCH

4

WITHIN a single lifetime the atom has changed its aspect completely. When Roentgen, Becquerel and the Curies discovered the X-ray (1895), radioactivity (1896) and radium (1898) no-one had considered that the atom could have an interior. Less than sixty years later, scientists delve within the atomic nucleus and discover the maze of fundamental particles of matter and of energy that have been reported in the preceding articles: electrons and positrons, protons and neutrons, mesons and neutrinos.

These particles compose the atom as atoms compose the earth and the stars. All this new knowledge has multiplied the majesty and the mystery of the universe. It has had terribly destructive uses as well as enormously beneficial ones. But this is only the beginning. Far more will certainly be revealed in the next fifty years than in the past fifty.

The scale and pace of research have changed too. Roentgen and Becquerel made their discoveries almost accidentally by noticing that photographic plates wrapped in black paper, beyond the reach of light, had been fogged by unsuspected radiations from a vacuum tube in the one case and from a small package of uranium salts in the other. It was, to be sure, no accident that they investigated the cause of these mysteries and thus made their great discoveries.

A job for teamwork

IT was superb skill and vast patience that enabled Pierre and Marie Curie to track down the "Becquerel rays" and to discover their origin in radium. But those epoch-making researches were done in small, cold, university laboratories, at Wurzburg and at the Sorbonne in Paris, with a supply of plain dishes and a few simple but accurate instruments, designed and built by the investigators themselves—plus long hours of hard work, often at night after professorial duties.

Those days are gone. Today the frontiers of atomic science are so far from the everyday world that it takes large, expensive and organized expeditions to reach them. A cyclotron for penetrating the nucleus costs millions of dollars. To operate it at thousands of horsepower costs thousands of dollars per day and requires the combined work of large teams of physicists, chemists, mathematicians, engineers, electricians and also biologists and physicians.

The whole undertaking is so expensive that no university anywhere can establish a modern nuclear research laboratory without the financial aid of its government. And there are very few governments in these days of economic strain that can afford a major programme of nuclear research. So most students and scientists the world over have little chance of participating in this greatest scientific adventure of the twentieth century. Yet the pioneer work had been European.

The European Cultural Conference meeting at Lausanne in 1949, first recommended that specialized European institutes be established in fields where the costs exceed the resources of individual governments and specifically urged the setting up of such an institute in nuclear physics. At the General Conference of Unesco at Florence, Italy, in 1950, Professor Isidor Rabi of Columbia University in New York, proposed that Unesco should take the lead in bringing together European scientists and governments to establish a European centre for nuclear research using their combined intellectual and financial resources. Three years later, in July 1953, the Convention for the European Organization for Nuclear Research, drawn up under Unesco auspices, was signed at the Ministry of Foreign Affairs in Paris. It will be a reality when formally ratified by seven nations.

The resolution passed by the Unesco General Conference at Florence was, in fact, somewhat broader. It authorized the Director-General "to assist and encourage the formation and organization of regional research centres and laboratories in order to increase and make more fruitful the international collaboration of scientists in the search for new knowledge in fields where the effort of any one country in the region is insufficient for the task".

Thus Unesco has also sponsored the establishment of an International Computation Centre, probably to be located in Rome, where modern electronic computers will be available for the use of the scientists of member nations. And, on the other side of the earth, Unesco is studying the possibility of an international research centre in oceanography in the Indo-Pacific region.

Twelve European nations have taken part in the discussions and planning and are expected to become members of the European Organization for Nuclear Research. They are: Belgium, Denmark, France, the German Federal Republic, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia. Other states may later be admitted to membership by unanimous vote of the member states. The cost is estimated at 120 million Swiss francs (28 million dollars, 10 million pounds sterling) for the first seven years, including construction and operation, which will be provided by the member states in proportion to their average national incomes.

Rivalling cosmic rays

WHILE the new organization will actively foster the co-operation between separate national research centres especially in nuclear theory, it will have a central laboratory located on a site approximately 2,000 feet square about three miles northwest of Geneva, Switzerland, and adjoining the French border on land offered by the Geneva Canton.

A staff of about fifty experts, many of them part-time consultants, has been at work for a year and a half on detailed plans for the buildings and the powerful machines. The Secretary-General is Professor Edoardo Amaldi, professor of Experimental physics at the University of Rome. The group responsible for the design of the laboratory itself is headed by Professor Lew Kowarski, Scientific Director in the Atomic Energy Commission, France, while the Director of the theoretical group is Professor Niels Bohr, Director of the Institute of Theoretical physics in Copenhagen.

There are also two special study groups for the design of the two major high-energy accelerators. That for the 600 million electron-volt synchro-cyclotron is headed by Dr. C.J. Bakker, professor of physics at the University of Amsterdam, and that for the great 25 thousand million electron-volt proton-synchrotron is under Dr. Odd Dahl, Head of the Section for Applied physics at the Michelsen Institute in Bergen Norway.

The smaller of the two machines will have ample power to generate mesons for detailed study. It will have an electro-magnet sixteen feet in diameter, weighing 2,500 tons and fitted with two electric magnetizing coils that together will weigh another 180 tons. It will be surrounded by a thick concrete wall and covered by a concrete roof. It will cost about 17 million Swiss francs (4 million dollars, 1.4 million pounds sterling) and will take about four years to build so that it should be ready for operation in 1957 or 1958.

The proton-synchrotron, however, will be far larger and more costly. It will generate particles with ten times as much energy as is provided by any existing machine and will embody a recently discovered principle for controlling them. It will be the first machine to produce particles with as much energy as is carried by the cosmic rays from outer space. No one can predict what it will reveal but the experts have great expectations of reaching the inner secrets both of matter and of energy.

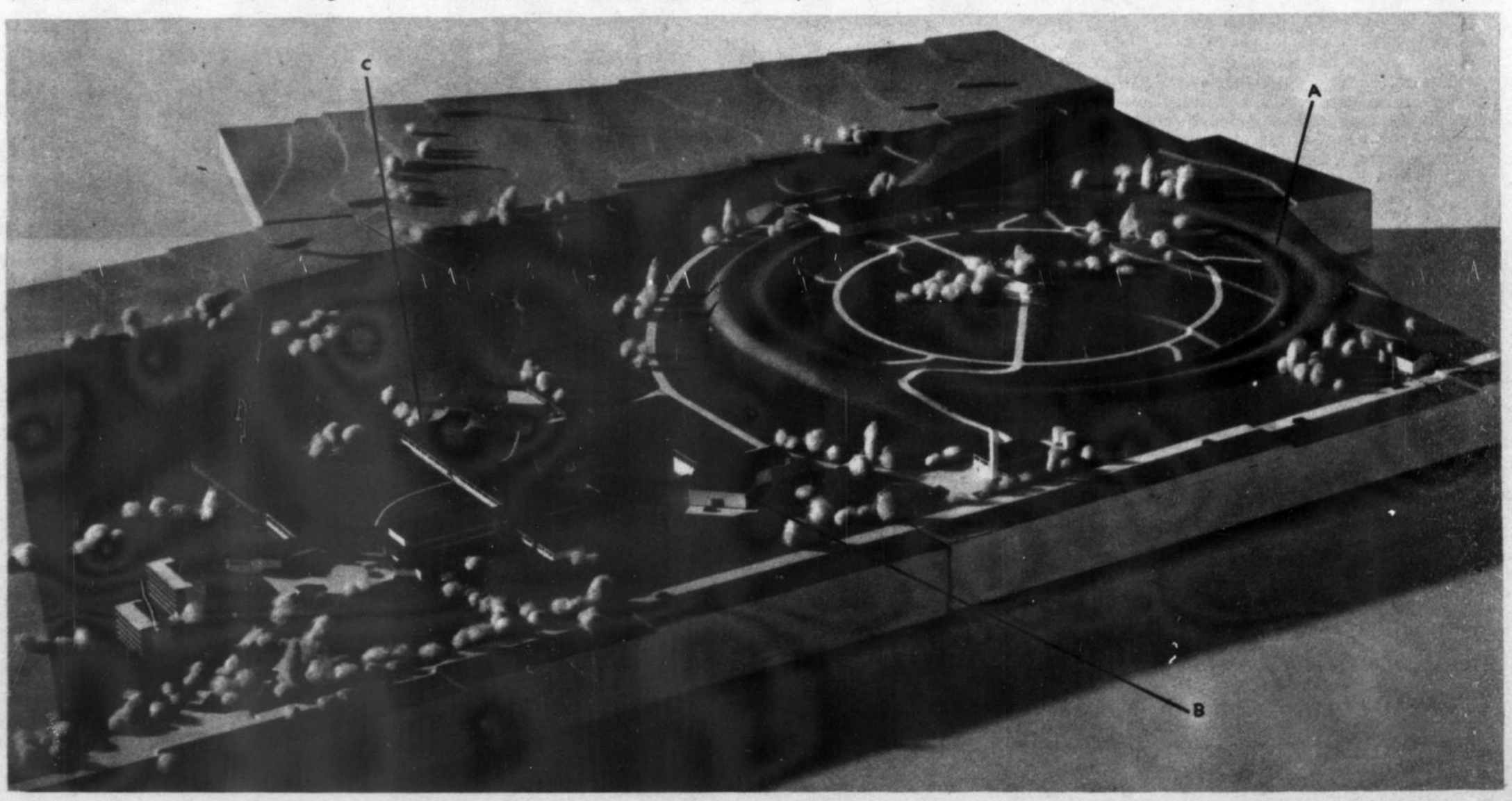
Its great magnet will be relatively small in cross-section but will form a circle some 650 feet in diameter, buried in a deep trench in the earth and covered with thick concrete. Each time a high-speed particle goes around the ring it will travel nearly —2.000 feet and in half a million circuits—which would require only a little more than a second—it will travel as far as from the earth to the moon, at practically the velocity of light. Emerging then it will be the most energetic projectile ever produced by man.

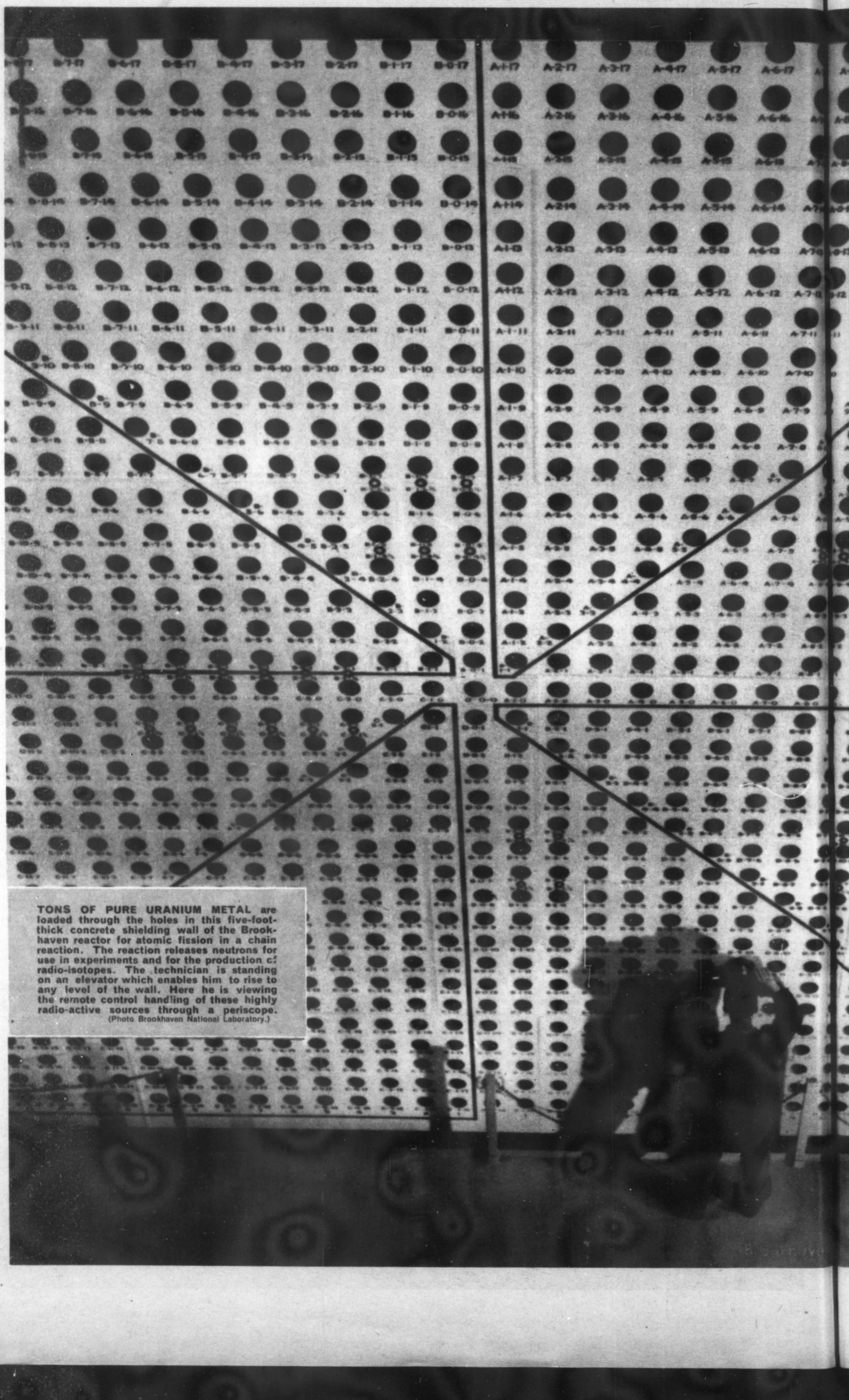
The proton-synchrotron will cost about 55 million Swiss francs (12.8 million dollars, 4.5 million pounds sterling) and will probably take seven years to build so that it will not be ready for use until 1960.

It is important to mention that the Convention of the European Organization for Nuclear Research states that its purpose is "to provide for collaboration among European States in nuclear research of a pure scientific and fundamental character". Also, it "shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or... made generally available".

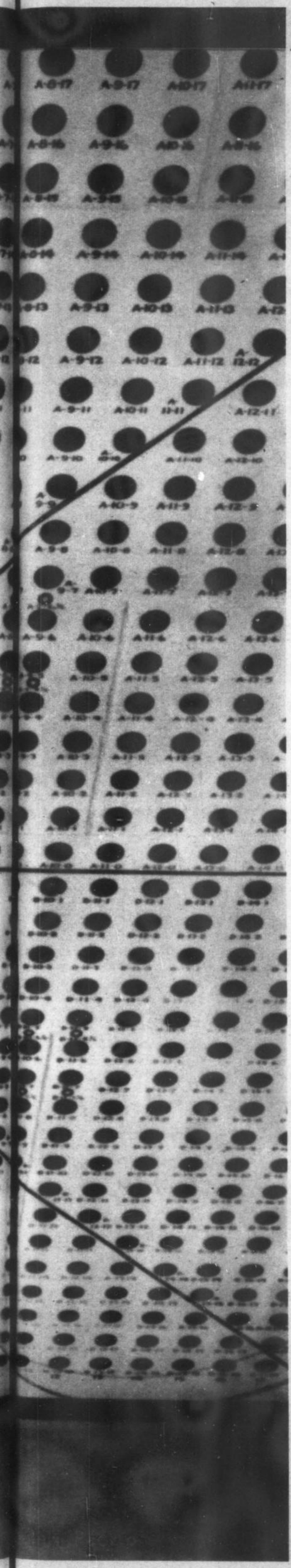
This means that its work will have no relation to war and none of its results will be secret but will be the property of mankind. It will, in fact, be the beginning of a new era in science, one of maximum co-operation among scientists across national and linguistic borders, and a common peaceful effort to master the secrets of nature in order to increase the resources of humanity.

A model of the future European Laboratory for Nuclear Research which will house the world's most powerful instruments to explore matter and energy at Meyrin, near Geneva. The centre's proton-synchrotron (A) will be the largest of its kind in the world. Its giant magnet (some 600 feet in diameter) is buried in a concrete filled trench. The building to house another giant machine, a synchro-cyclotron is shown at B. Remaining buildings (C) are laboratories and workshops.





TONS OF PURE URANIUM METAL are loaded through the holes in this five-foot-thick concrete shielding wall of the Brookhaven reactor for atomic fission in a chain reaction. The reaction releases neutrons for use in experiments and for the production of radio-isotopes. The technician is standing on an elevator which enables him to rise to any level of the wall. Here he is viewing the remote control handling of these highly radio-active sources through a periscope.
(Photo Brookhaven National Laboratory.)



5 ISOTOPES

RADIO-ACTIVE ATOMS FOR EVERYDAY USE

WHEN America was discovered in 1492 the first reaction of the civilized world was astonishment at the revelation that so great a continent, so peopled with strange tribes and so wealthy in resources, had always been there, quite unknown to Europeans. The world suddenly became much larger than anyone had thought and, far from being flat, was soon shown to be a globe when Magellan sailed completely around it. Then came the great stories of adventure and exploration, which lasted for a century. Then came settlements in the new land, and colonies and finally the great nations that now comprise one-tenth of the human race.

The history of most discoveries in pure science is similar. First the interest is philosophical and lies in the further revelation of the complexity and glory of nature. Then it becomes an absorbing story of conquest and understanding. Finally the new knowledge becomes useful and valuable to human living. So it is with nuclear science.

The preceding articles in this series have explained the fundamentals of the new knowledge of the world within the atom. It remains to discuss its uses which are already large and diverse. Although they are still in their infancy, they are enough to prove that this is one of the great discoveries of all time, comparable to the invention of the microscope and of the steam engine, in its benefits to science and to humanity.

But the most impressive, yet terrible single use, and one which cannot be ignored, is in military explosives. This use is dominant in the minds of men because of its awful threat to humanity but, from a broad point of view, it was a development of only one aspect of the new knowledge forced by military necessity. It is an accident of history that the discovery that energy can be obtained from one special type of atom came just at the moment when the greatest war of history began. But in the long run the year 1939 may well be better remembered for the discovery of atomic energy than for the inception of World War II..

The studies of nuclear structure that have here been described all involve the use of tremendous energy concentrated in high-speed particles in order to form a very few tiny nuclear fragments. It is a vast expenditure of energy with no gain.

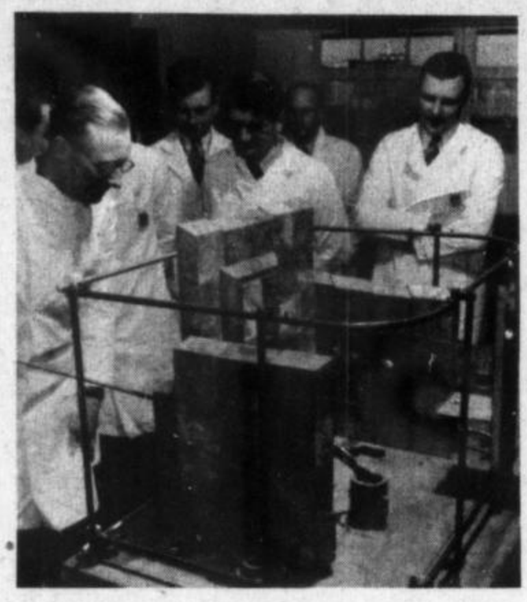
But there is one case in which an atom, thus disintegrated by a collision with a neutron, gives out more energy than it receives. That is the case of the relatively little known metals, uranium and thorium. It is their excessive energy that can be utilized for destruction. Whether or not it will ever again be so used we do not know, but it is quite certain that it will be employed on a large scale for peaceful purposes. An age of atomic energy in industry lies ahead, at least in those countries that have no resources in coal or petroleum.

One pound = 1,500 tons

IT is now well known that one pound of uranium can yield as much power or heat as 1,500 tons of coal. But this does not mean that energy from this source is cheaper than energy from coal. Even if the uranium cost nothing at all, the cost of its energy would still be high because of the very large and expensive equipment that is needed to generate it. Wherever coal or oil are cheap, hence wherever they are close at hand, they will remain the chief source of industrial power. But where coal is costly because it must be transported long distances, atomic fuel is economical, even now.

While the direct use of atomic power is still in the future there are already literally thousands of valuable uses for the rays and for the materials that have been made commonly available by the progress of nuclear physics. Industry, agriculture, medicine and the biological sciences are making large use of them in the form of isotopes—those elements that are not found in nature but are produced by nuclear collisions in the cyclotron or by neutrons emitted by uranium in the atomic furnaces.

More than 32,000 shipments of radio-active isotopes and more than 2,000 shipments of non-radio-active, or stable, isotopes have been made by the U.S. Atomic Energy Commission to more than a thousand institutions in the U.S.A. and 1,600 shipments of radio-isotopes have been made to some 350 institutions in 33 other countries. Many industrial firms and thousands of physicians the world over are making daily practical use of them.



WHEN DEALING with radio-active chemicals on a laboratory scale, a wall of two-inch-thick lead bricks offers sufficient protection against dangerous rays emanating from such materials. More elaborate precautions are needed in large scale atomic energy plants. Here, at the Atomic Energy Research Establishment, Harwell, England, students see a demonstration of how a chemical can be put into an isotope container with tongs. Lead containers are used for the transportation of isotopes.

(Photo British Crown Copyright Reserved.)

MOST ISOTOPES are stored in liquid solutions. Technicians operate by overhead mirror, behind two-foot concrete wall (Radio-active waves shoot sideways but not vertically). Bottles are filled, packed and withdrawn by an ingenious "master-slave" manipulator, a remotely controlled device which can duplicate the motion of a hand.

GLASS VIAL inside which the radio-isotope will be shipped, is protected by steel cup, absorbant paper, and concrete or lead shielding, depending on kind of radiation which is involved.

(Photos Oak Ridge National Laboratory.)

Industrial applications

A typical industrial use of the rays from these radio-active materials is in the automatic control of the production of thin sheets of paper or plastic, or the metal for making tin cans. As the sheet leaves the rollers which squeeze it to the desired thickness, it passes through an instrument that holds a small amount of radio-active material under the sheet and holds a detecting instrument, such as a Geiger counter, over the sheet. The rays penetrate the sheet and are received and detected on the other side.

But if the sheet for some reason becomes either thinner or thicker than is desired the amount of radiation received by the detecting instrument instantly increases or decreases as a result, because it is partly absorbed in the sheet. Thus the instrument is a constant and automatic inspector of the thickness and it can easily be adjusted to regulate the rollers and correct the error so as to produce a sheet of uniform thickness.

Another example of the direct industrial use of the radiations from isotopes is the control of the flow of oil through long pipe-lines. Such a line can seldom be used for long periods to deliver one single grade or variety of oil. Instead, different oils are pumped through, one after another. It is important for the operators at the receiving end to know when one grade or one shipment is at an end and another is to begin in the continuous flow of oil from the pipe.

This is now done by mixing in a small quantity of radio-active oil at the boundary between one batch and another as they are pumped into the pipe. When that radio-active oil reaches the receiving station, perhaps hundreds of miles away, the radiation counters immediately detect its arrival so that valves can be adjusted to shift the flow from one tank into another.

Another example from the oil industry illustrates the use of isotopes in research. The Shell Petroleum Company in England now measures friction and engine wear by exposing a piston ring to bombardment by neutrons until a small part of the iron is converted to a radioactive isotope. The ring is then fitted in an operating engine. As it wears by friction the debris goes into the crank case oil and that oil is then pumped through a sensitive detector of radiation. The very small quantity of weakly radioactive iron is sufficient to be measured and therefore to give an immediate indication of the amount of wear on the engine. This method of testing avoids the long operation of the engine and the troublesome analysis of the oil for iron, and can show the effect of different lubricants within minutes.

The California Research Corporation reports that in similar researches a programme of friction studies that would have taken 60 years and cost a million dollars was completed in this way in four years at a cost of thirty-five thousand dollars. Others have employed this method to show that high speed driving on the open road causes only about one-third of the engine wear that

(Cont'd on next page)

THE VERSATILE 'TRACER' – MAGIC EYE OF INDUSTRY FARMING AND MEDICINE

(Continued from previous page)

is involved in city driving. The end result of these researches, however, is the reduction of friction and the improvement of lubrication.

The rays from radio-active isotopes are also directly effective in causing the luminescence of crystalline materials used on watch dials and on out-door signs. These cheap isotopes have now replaced expensive radium for this use, Another application is in the ordinary fluorescent tube. When isotopes are mixed with the luminous material they increase the conductivity of the air in the tube so that it requires less voltage to start the lamp and it starts much more quickly. A similar use is made of a tube of such materials, weakly radio-active, where there is danger of sparks from static electricity. The faint rays make the air a sufficient conductor of electricity so that static does not accumulate.

For the future, one of the most promising uses is likely to take the form a semi-permanent low-power electrical generator. One of the isotopes of strontium, spread on an electrode in a vacuum tube, emits electrons, hence emits negative electricity and itself becomes positively charged. A voltage as high as 365,000 volts has thus been obtained. Experiments are in progress to utilize this generation of electricity to operate a small direct current motor which would require no other source of power.

Bacteria-killing rays

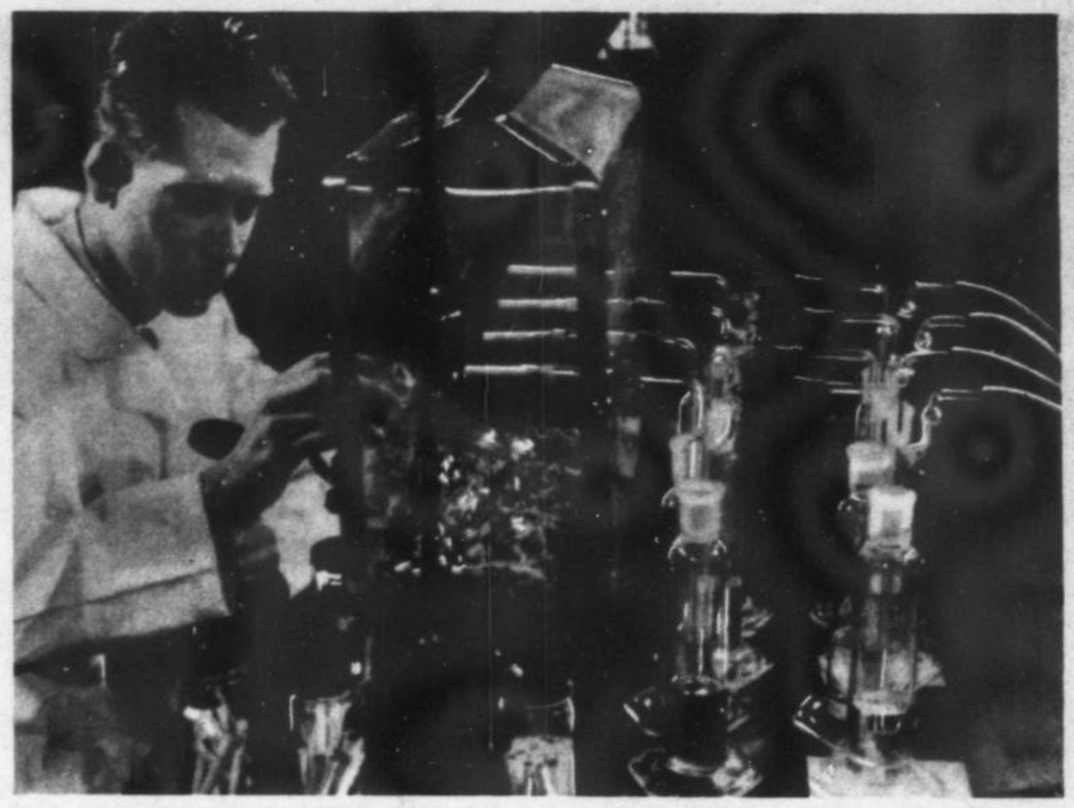
IN other industrial plants, the penetrating rays from isotopes are now replacing complicated X-ray methods for testing the structure of metal parts. In still another application they are used to measure the height of liquids in tanks by having an isotope in a float on the surface and reading the position of this float by the rays that are emitted through the tank walls. This method can even be used to measure the height of molten metal in a foundry tank.

The radioactive isotopes described in the above examples are only faintly radioactive, sufficient to be detected by the right instrument but not sufficient to do harm to living things. But extremely powerful isotopes are also available. In the case of the metal cobalt, for instance, it is possible to obtain an isotope thousands of times stronger than radium itself, so that a small tumbler of the material gives as powerful a radiation as a whole kilogram of radium.

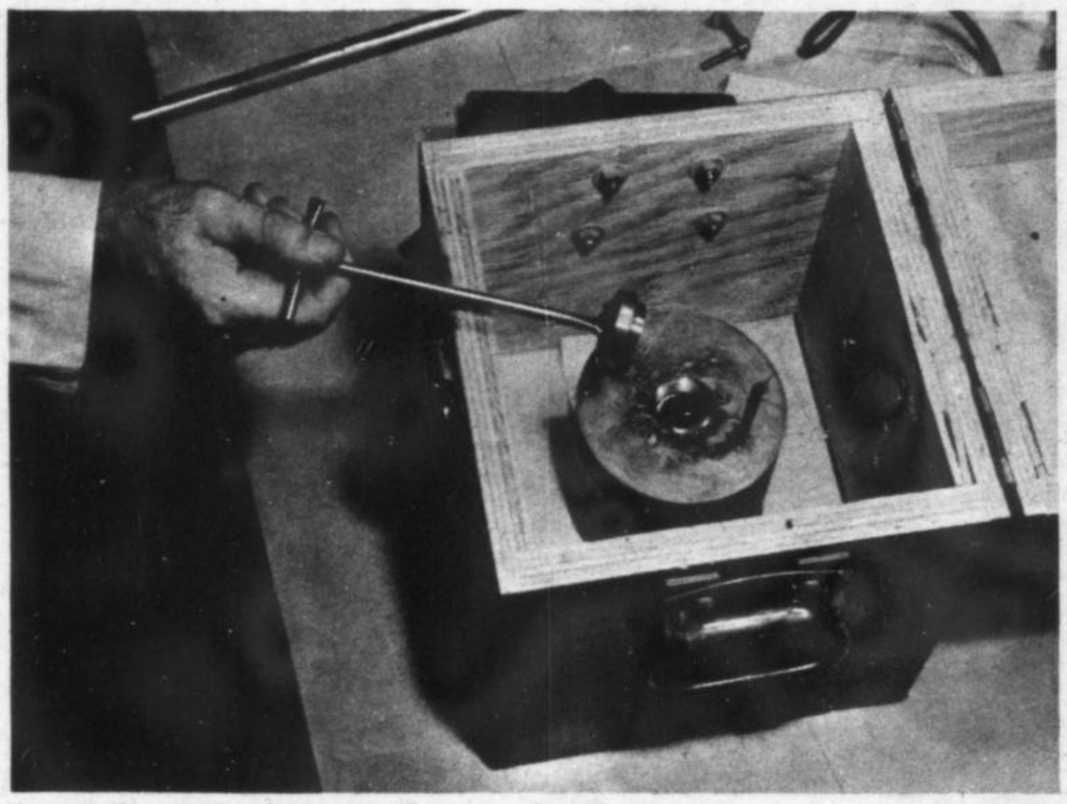
In such strength, the rays can be used to destroy bacteria and even larger forms of life. One of the most interesting possibilities therefore is the sterilization of drugs, medical supplies, and foods merely by exposing them to the rays from this form of cobalt for a few seconds or minutes. Complete sterilization can be obtained without the use of heat, a point which is very important in the case of drugs that are decomposed by heat and for many foods whose composition and flavour are changed by the usual processes of sterilizing by cooking.

Perhaps the most immediate use of this process is in the manufacture of penicillin, the drug that is now so widely employed for the cure and prevention of infectious bacterial diseases. The total annual production of penicillin per year is now worth well over a hundred million dollars (36,000,000 pounds). Since the drug is used in the human body, it must be completely free from living organisms, yet it cannot easily be sterilized by heat without partial decomposition. As soon as the cost of radio-active cobalt becomes somewhat less than at present, many kilogrammes of it could be put to work for the sterilization of this drug.

The production of radio-active cobalt would have to grow still larger and become still cheaper before the same process could be used for the sterilization of foods. In this case, a source of very penetrating rays would be used which would completely sterilize the interior of a cut of meat or of a large vegetable. Canned hams, for instance, are not now generally satisfactory because of their flavour and their lack of complete stability. They could be sterilized in the cold by the use of radio-active isotopes without affecting the flavour and would remain sterile if their surface were protected.



RADIO-ACTIVE ISOTOPES are now being used in amazing ways in industry, medicine, agriculture and the biological sciences. This photograph shows an isotope which is being used to strain out the nicotine from cigarettes. (Photos USIS.)



OPENING A SHIPMENT OF ISOTOPES. A special key supplied with the package fits slot in screw top of inner stainless steel container so that it can be unfastened and removed, as shown, without need of retouching it with hands.

THIS PISTOL MONITOR is typical of the portable health instruments used in work with radio-active substances. It is used to measure the intensity of either beta or gamma rays in laboratories. (Photo British Crown Copyright Reserved.)

An even larger possible use is the sterilization of fresh fruits or vegetables. These at present remain fresh for only a very short period. If they were sterilized cold by radiation they would retain their flavour and, if properly packaged, would not spoil for long periods of time. They could be sterilized immediately after picking and retained on the market for months afterwards.

Rejuvenated pastures

ANOTHER utilization of this same method is the destruction of organisms on the surface of foods. The skin of the fruit is the usual source of spoilage and provides an almost ideal medium for the growth of bacteria. It would be a relatively simple matter to sterilize the skin and outer surface without the use of heat. This system could be applied to fresh tomatoes, apples, peaches, melons, nuts, eggs, cucumbers, grapes, and oranges. Since only the surface would be sterilized, they would not remain fresh for months but they could be kept for several weeks before being sold or eaten. It would also be applicable in the case of packaged foods, such as bakery products, which in some countries are now sold in plastic or paper wrappers. A surface treatment with radiation would preserve them.

The production of radio-active isotopes of this strength is not yet sufficient for these uses and the cost is also at present too high, but the advantage to the food industry in cold sterilization may make it possible to produce isotopes for this purpose in huge volume and at low cost. When atomic fuels are used for the generation of large quantities of power in industry, very great amounts of these radio-active isotopes will become available as by-products.

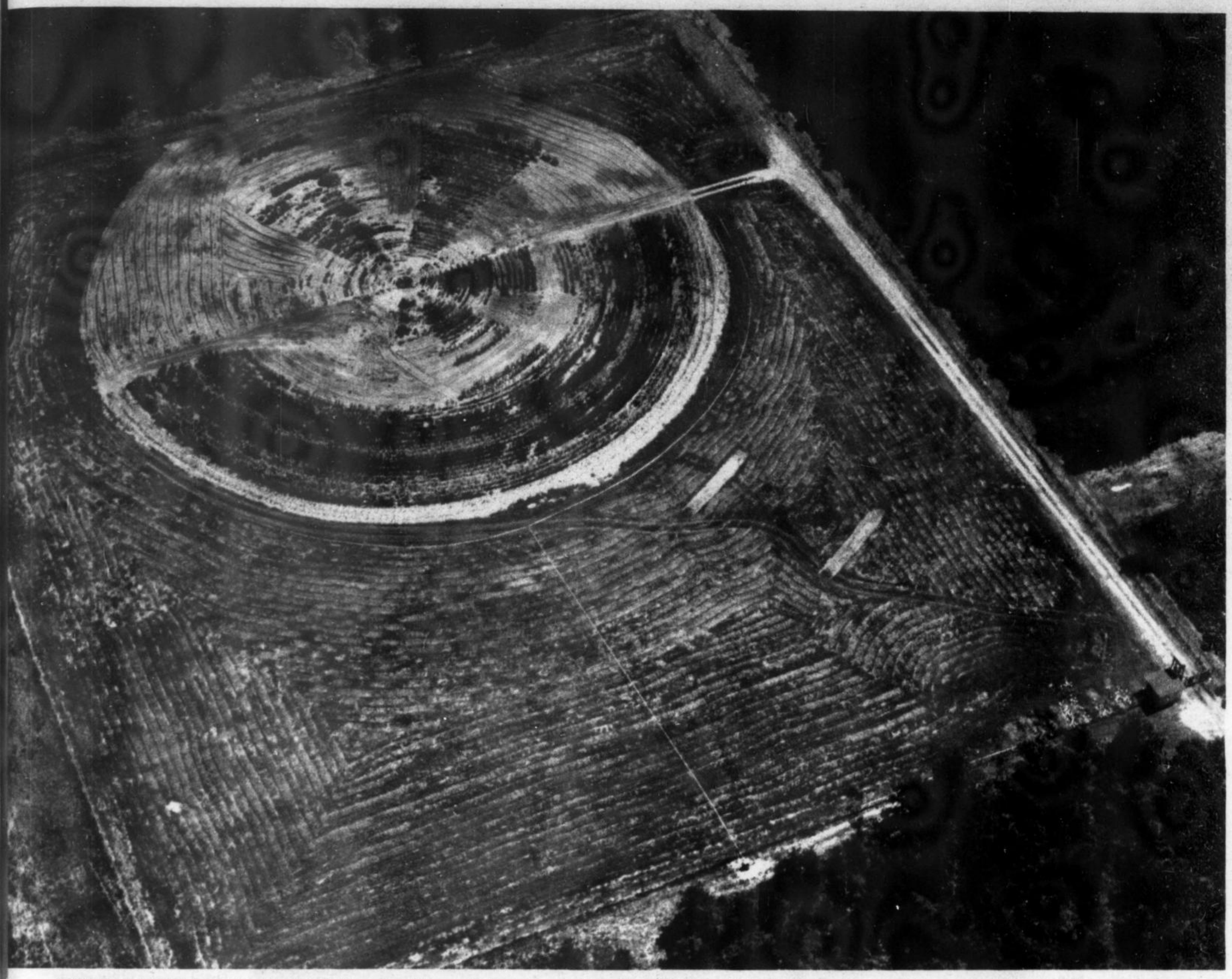
There is no direct application of these powerful rays in agriculture, biology, or medicine except in cases where destruction is desired, such as the eradication of a cancer. But the use of radio-active isotopes in these sciences is nevertheless enormous by quite a different technique. This consists in using the chemical elements that occur in animals, plants and plant foods, with a very small admixture of the radio-active form of the same element.

For example, phosphate is a necessary plant food and is a component of nearly all fertilizers. It is an easy matter to produce the isotope of phosphorus that is weakly radio-active and to mix it with the normal phosphate in the fertilizer. Since it constantly gives off a weak and harmless radiation that can be detected by proper instruments, it is a very simple matter to follow or trace what happens to the phosphorus in the soil and in the plant. Used in this way, phosphorus would be called a "tracer".

Important agricultural information has thus been obtained. For instance, Swedish investigators have found that phosphate in a fertilizer is taken up by the plant roots almost immediately when it is spread on the soil; there is no delay. American investigators have discovered that pasture grasses can take up phosphate that is spread over their leaves and roots, so that old pastures can be rejuvenated by phosphate without the need for ploughing.

Even more interesting is the fact that maize, sugar beets, tobacco and cotton take up phosphate from the fertilizer only during the early stage of growth. Fertilizer spread on the soil late in the season is of no value to these crops. On the other hand, potatoes take up phosphate from the fertilizer in large quantities throughout their entire growing season.

Finally, it has been found that phosphoric acid added to irrigation water is just as effective as fertilizer spread dry on the soil. All of these results were obtained by measuring the amount of radio-active phosphorus detected in the growing



GENERAL VIEW from the air of a field at Brookhaven National Laboratory, New York, used for plant experiments with nuclear radiation. Maize and other crops are planted in circular furrows around a central source of radiation, radio-cobalt. Mutations and other changes in cell structure of plants are induced by exposure to gamma rays emitted by the radio-active cobalt. Scientists are studying results which may eventually lead to improved strains of maize and also other vegetables.

plant. While its quantity is small, like the black sheep in a flock, it can reliably be used for measuring the fate of all the phosphorus.

Many other tracer elements utilized in this manner have given information of value to the farmer. Radio-active potassium, painted on a branch of a dormant plum tree, in weather below freezing point, was found to enter the sap and move several feet both up and down the branch in spite of the fact that the sap is supposed to be motionless in winter. On the other hand, in summer the phosphorus moves all the way to the roots within twenty-four hours.

Another agricultural application of this tracer technique with radio-isotopes is in the study of insects and fungi. Radio-iodine has been used to study the spread of the oak wilt fungus, through the roots and from the roots of one oak to another. Insecticides also can be tagged with radio-isotopes. Thus it has been shown that plant leaves absorb insecticides principally on their under surface and do so only during the day. Such work has also emphasized the difference between broad-leafed plants and narrow-leafed grain and grasses in their reponse to such weed-killers as 2,4-D. A broad-leafed plant absorbs a weed-killer sprayed upon it and within two hours the entire plant is permeated with it. On the other hand, the grasses absorb very little weed-killers and what is absorbed stays on the spot without affecting the plant as a whole.

Replacement for radium

EVEN mosquitoes can be traced by radio-isotopes. Mosquito larvae that swim in a very weak solution of radio-phosphorus remain radio-active all through their lives and their presence can be detected with Geiger counters. The habits of mosquitoes are now being studied by this method to learn how long they live, how far they fly, and what they feed on. It is expected that similar treatment of birds may give reliable information on bird habits and especially on their migrations.

The use of the powerful tissue-destroying rays from radium is established in the treatment of cancers. They have the same effect as equally powerful X-rays but a cancer can often be reached with a small pellet or tube of radium that cannot well be reached by X-ray tube. The new radio-isotopes can be used in exactly the same way, but with the advantage that the amounts of radiation that can be obtained from them are far larger than in the case of radium and they cost less.

The commonest substitute for radium is radio-cobalt. A small cylinder of metallic cobalt gives gamma rays equal to that of radium costing several hundred thousand pounds sterling. Such a piece of cobalt, weighing little more than an ounce is enclosed in heavy metal but an intense beam of radiation is directed through a small window at the cancerous growth.

In other forms, both radio-phosphorus and radio-gold are very conveniently used for this type of treatment. For skin cancers, an ordinary blotting paper is soaked with radio-active phosphate solution and when dry it is cut to the size and shape of the tumor, then is strapped to the tumor with adhesive. Radio-cobalt can be drawn out into a fine wire or cut into tiny beads which can be placed within the cancerous growth. And radio-gold can be formed into tiny grains which are fired directly into the cancer from a small "gun". In both cases they remain in the cancer until it is destroyed.

In another method of treatment, the radio-isotope can be given internally or can even be swallowed to find its way into the blood stream. It is absorbed from the blood by cancerous tissue. This is one of the respects in which cancer differs from ordinary tissue: it does absorb the radio-isotope. Consequently, one disease, in which the red blood cells are formed in such profusion as to clog the blood vessels, can be treated by radio-phosphorus which sharply reduces the production of red blood cells in the body for a period of about a year.

Body-building revealed

THE element iodine is freely absorbed by the thyroid gland which uses it to make the hormone called thyroxine. In patients whose thyroid gland is too active, so that it produces too much thyroxine, part of the thyroid was formerly removed by surgery. Nowadays, a glass full of a solution of radio-iodine serves the same purpose since iodine is absorbed in the gland and there emits its rays which destroy the excess thyroid tissue and activity. This is, however, not a cancerous condition and cancer of the thyroid is in fact not easily treated with radio-iodine.

In a few such uses, radio-isotopes have been extremely valuable. However, their chief use in medicine is not for treatment but for research, where the purpose is to trace the course of chemical and physiological processes in the body. The isotopes used are those that give weak and harmless rays that can easily be detected by the proper sensitive instruments. In some cases isotopes, are used that are not radio-active, heavy water, for example, and must be detected by more complicated methods.

One of the first results of the use of "tracer" isotopes was the discovery that all the tissues in the body are in a constant process of replacement. It is natural to think of the body as a stable structure which uses food only to maintain its heat and for replacement of worn parts. This is not so. When fats, in which some of the hydrogen atoms have been replaced chemically by "heavy hydrogen" are eaten, the new fat is deposited in the fatty layers of the body while the older fats, already in the body, are burned for heat.

So, too, eating proteins which contain "heavy nitrogen" results in the use of the fresh protein for building body tissues, muscles and blood cells, while the proteins already present are oxidized and excreted. Every part of the body is thus constantly being rebuilt by a steady exchange of new materials from food to replace the established materials.

In a relatively short time, a matter of weeks or months, every human or animal body is completely rebuilt. Even the bones are thus rebuilt and the only exception is the iron, chiefly in the red blood cells, which is not rapidly replaced by new iron atoms in the food. This process is a fundamental to life, but would probably never have been discovered without the use of tracer isotopes.

Animals and plants can seldom distinguish between ordinary atoms and the unnatural isotopes. The fact that there are now more than six hundred different isotopes available, some of them in large quantities, has made possible the investigation of a very large number of biological reactions, so that the tracer technique has provided almost as much information about living things and the life process as did the microscope during the first few centuries after its invention. This is partly because an isotopic atom can be followed through a long succession of changes.

For instance, the actual function of vitamins and how they do their work in nutrition has recently become entirely clear by this method, though it is too long a story to tell here. One example is the addition of radio-cobalt to the culture medium on which the mould *Streptomyces griseus* is grown. The mould takes up the isotopes and uses them to manufacture vitamin B-12 and they can be detected by their rays both in the mould and in the vitamin that is later produced from the mould. Thus a radio-

(Cont'd on next page)

DATING THE PAST WITH NATURE'S CLOCK

(Continued from previous page)

active vitamin can be used in the food of human beings and its fate in the chemistry of the body traced.

The most promising investigation of this sort is the study of the process by which green plants build their substance from the water and carbon-dioxide of the air. This reaction is the fundamental one for all life since all the green plants depend upon it and all other plants and all animals depend on the green plants. It is apparently a simple reaction in which the molecule of water and that of carbon-dioxide are combined, lose some oxygen, and form sugars, starches, cellulose, and more involved chemical materials.

Nevertheless, no one knows how the plant does it and man is unable to duplicate the reaction. But the availability of a faintly radio-active isotope of carbon has already given much information and may within the next year or two explain the reaction completely. This will not mean that man can dispense with plants for food production, but it may well mean that the food production by plants can be greatly improved once this reaction is understood.

The process involves the formation of carbon-dioxide gas from carbon which contains a small proportion of the radio-active isotope of carbon. The product is "heavy carbon-dioxide" but is used by plants in the presence of sunlight exactly as they use ordinary carbon. The result is that the radio-active carbon is built into the materials of the plant and its presence and location in the plant can be detected immediately. When the green leaves of certain plants were thus exposed to radio-active carbon-dioxide for only one minute, at least fifty separate compounds were found in the leaf, tagged with radio-carbon. When the time of exposure to sunlight was reduced to two seconds, the leaf had already manufactured two or three compounds from the carbon-dioxide of the air.

It turns out that the first products made by the plant are compounds of phosphoglyceric acid which thus are shown to be steps in the manufacture of fruit, or grain, or sugar. After two minutes of exposure, radio-carbon tests showed that even proteins and fats already contained the new carbon just received from the atmosphere. The detailed investigations of these reactions are now in process and the full mechanism of this basic plant reaction should be understood very soon.

By studying the process in different plants it is now known that the early stages of the reaction are identical in all plants. Only later does the process diverge into the production of compounds that are characteristic of each plant, such as aromas, colours, and drugs. In the case of the green algae, it has thus been possible to divert the reaction among the algae so that either a preponderance of sugar or of malic acid can be formed early in the process.

On this basis, the experiments have now been continued to show that the same algae which normally contain about 50 % of protein can be so altered as to produce about 75 % of fat instead of protein. In fact, the protein content can be varied all the way from 7 % to 88 %, while the fat content can be changed from 1 % to 75 %. At the same time, the carbon-dioxide can be changed from 6 % to 38 %. This obviously opens enormous possibilities for changing and increasing the food supplies available both to animals and to human beings.

One more chapter must be added to the achievements of the radio-isotopes, namely that they have provided a new measure for historical time. They have given answers to questions on the age of trees and of long-buried animals, of human skeletons and of human structures of centuries ago. They have dated the Ice Age and are capable of fixing closely the dates of many events within the last 30 thousand years.

The method is based on the fact that there is a very small but definite proportion of the heavy radio-active isotope of carbon in all the carbon dioxide of the atmosphere. Since all plants build their tissues from that carbon dioxide and all animals breathe it, the proportion of radio-active carbon to ordinary carbon in all living things is the same and is as well-known scientific fact.

As soon as an animal or a plant dies, the exchange of carbon with its surroundings ceases and many are buried and partly preserved.

As soon as this happens, a slow change in the proportion of the two isotopes occurs. The radio-active isotope gives off its rays and becomes inert so that it can no longer be detected. But this is a slow process. Any amount of radio-active carbon is reduced to half the original quantity in 5,568 years, then to half of that, therefore to a fourth of the original, in another 5,568 years. In the course of about 30 thousand years what remains is too small to measure.

Within those 30,000 years, however, it is possible to measure the radio-activity of the carbon present, to compare it with the total carbon and thus to get an estimate of the date at which the plant or animal died. By this method it is now possible to fix the exact date when there was life in buried skeletons, the wood found in old structures, the charred remains from prehistoric fires, and even the organic material of mud.

Using this method, scientists at the University of Chicago have found that charcoal left from the ancient settlement of Shahèinab near Khartoum (Sudan) is from trees which were growing 5,060 years ago, while shells of bi-valves found in the same place were taken from the sea 5,446 years ago. At Jarmo, in Irak, is a site of an ancient village which shows the earliest traces of granaries and of a food producing economy. These were shown to be 6,695 years old. A Mayan lintel was carved 1,470 years ago, while the famous Stonehenge in England is dated at 3,800 years ago, thus nearly 2,000 years B.C. A pair of rope sandals in so good a state of preservation that they look as if they had been thrust aside only yesterday were found in a cave in Oregon, (U.S.A.). A test showed they were 9,000 years old.

Another recent question was the age of a manuscript scroll of the Old Testament book of Isaiah. Was it written in the days of the Old Testament or was it a medieval forgery? Analysis proved that it was written some 2,000 years ago but it could not be decided if it had been written before or after the life of Christ.

The oldest date for human life so far fixed in this way is the Lascaux cave in southwest France, site of the famous paintings of the extinct woolly mammoth. Analyses proved that this cave was inhabited and used by man about 15,500 years ago. On the other hand, there are remains of the flesh and hair of the ancient super-bison in Alaska which are older than 28,000 years, yet the flesh is in sufficient preservation so that arctic dogs have eaten it.

Perhaps the most surprising discovery relates to the circulation of the water in the oceans. At the surface ocean water contains the normal proportion of radio-carbon and ordinary carbon but in the arctic regions the surface water sinks and is known to move slowly along the ocean bottom toward the tropics, so that there is a constant circulation.

Measurements of samples of water taken deep in the Atlantic opposite Newfoundland showed that the organic material in the water was about 1,500 years old. It is therefore a matter of several thousands of years for the slow ocean currents to turn over the surface water to the bottom and bring bottom water up.

Another interesting date is that of the last ice sheet which covered northern Europe, Asia, and America. Its date has now been set by measuring the age of the trees and wooden debris that lie under the gravel deposited by the glacier. The date is 11,000 years ago. Since then, the glaciers have been retreating and still are. This has been confirmed by a study of the muds on the sea coast especially in the deltas of great rivers.

During the Ice Age, there was so much water frozen in the glaciers that the ocean level was much lower than it is now. At the height of the glacial period, the sea level was about 80 feet lower than now; 9,000 years ago, it was 70 feet lower; 7,000 years ago, 50 feet lower, and 3,000 years ago, 25 feet lower. Sea level is still rising, as the arctic and antarctic ice melts.

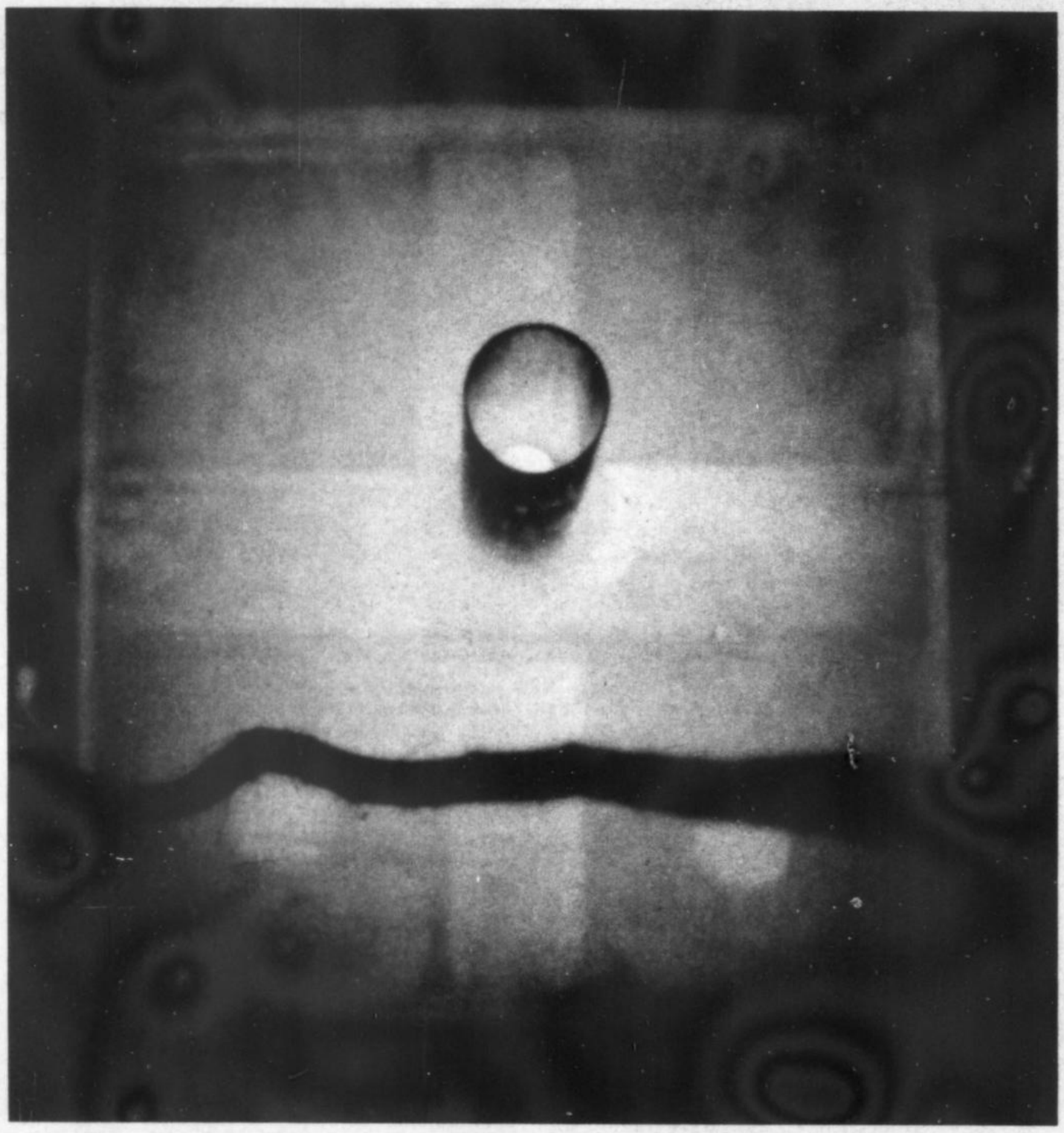
This method has been used also to measure the rate of formation of plankton, the very fine vegetable and animal matter that lives in the ocean and on which the smallest fish feed. An exploring vessel determined that, every year, every square yard of ocean produces three thousandths of an ounce. This may seem little enough, but in all the areas of the seas it amounts to 40 thousand million tons of carbohydrates every year—as much as is produced by all the trees and plants on land. Incidentally, this investigation showed that organic matter in the seas off the western coast of Africa is four or five times higher than that in the Indian Ocean. Further such studies can be used to locate future profitable fishing grounds.

A related problem solved some 30 years ago is the age of the earth. During the last century estimates have varied from a few thousand years, according to biblical documents, up to many millions. The most reliable measurement, and one now everywhere accepted, is based on the radio-activity of uranium and its slow decay into lead. The half-life of uranium is 700 million years, so long a period that there is still uranium on the earth in spite of its constant decomposition into lead. By measuring the amount of uranium now present together with the amount of lead formed from it, and comparing it with the known rate of decay of uranium, the resulting age of the earth is found to be approximately 3 thousand million years.

Thus the radio-isotopes have opened a new chapter in science by providing a reliable clock for the measurement of time which is long since gone.

Up to now only small quantities of radio-isotopes are available. If and when atomic power, and therefore atomic furnaces, are widely used by industry throughout the world, the production of radio-isotopes as a by-product of atomic furnaces will also greatly increase.

It is therefore safe to say that both the direct uses of the isotopes and the scientific discoveries made with them will greatly increase and will multiply both man's knowledge and his power.



A VESSEL containing radio-active cobalt set into a tank of water is here photographed wholly by the luminescence of the water itself when excited by the powerful gamma rays from the cobalt. It is these rays that largely replaced those from radium in cancer therapy because cobalt is relatively cheap. (The black shadow is a wire which lay across the field of vision). (Photo : Brookhaven National Laboratory.)

Trying out Television in Japanese Classrooms

by Henry Cassirer

Television has come into Japanese homes in three cities—Tokyo, Osaka and Nagoya—where transmitters have been operating since early in 1953.

Teachers all over the world are forever hunting out new ways of breaking old routines. New ways, that is, of making subjects come alive. New ways of capturing youthful imagination and enthusiasm. In Japan, there is an especially interesting experiment now underway. Teachers have just joined forces with the national radio and television network. And together, they are trying to determine how television's magic powers can best be put to work in Japanese classrooms.

The basic idea of this new Japanese experiment is to find out exactly how the animated images of television can help young students take in abstract and complicated ideas. Often, teachers have used photographs and film-slides for just such a purpose. Sometimes films or radio talks have helped. Now, Japan's teachers have decided to go still further. Like teachers in France, the United States and a few other countries, they are trying out the teaching powers of the newest medium of all — television.

Here is what they are doing. Every afternoon at one o'clock, the national network sends out a fifteen minute programme intended for young viewers seated in their classrooms. The programmes go out over each of Japan's new transmitters — in Tokyo, Osaka and Nagoya — three transmitters that have been functioning only since the beginning of this year when Japan first began television broadcasting.

Special school programmes have now been added to those for general audiences. Japan's young students find educational television a new and lively medium of instruction. It aids teachers and supplements text-books in a truly vivid fashion.

(Photos : Broadcasting Corporation of Japan—N.H.K.)

At the same time, a few classes conveniently located near the capital have been selected for a guinea-pig role. These try-out classes are in both primary and secondary schools. They are probably the most important aspect of the whole experiment. For educational television is still so new and its techniques so untried, that before attempting to teach the youngsters, the programme producers themselves first have to do some pretty active research work. It is like serving an apprenticeship in a new trade.

And it is not always easy. Take this example, for instance. One education television producer a few months ago managed to create a special series that he called "Television Travels". In this programme, two children journeyed all over Japan — one of them a boy named Terebi, the other a little girl named Tereko. Everywhere they went, they spoke to the local inhabitants about their cities, their local monuments, and so on. It all seemed an excellent technique for teaching school children about their own country. And to make the idea even more appealing, the roles of little Terebi and Tereko were given not to young actors but to marionettes.

It did not work out well at all. When the teachers and the television experts checked up at the guinea-pig schools, they found that they had made a bad mistake. All the children had been so absorbed watching the puppets that they had not taken in any of the information. And anyway, the puppets had created a special atmosphere of unreality, and that, too, conflicted with the factual descriptions of the geography lessons.

Similar presentation problems have arisen in televising other experimental programmes. "Fables of the World" set out to tell fairy tales of many nations, but limited resources prevented the visual side of the programme from being attractive enough to make the story vivid.

However, other programmes have succeeded magnificently from the very start. One such success is a series called "Understanding Classical Art". It is meant for fifteen-year-olds, and it is produced with the help of specialists from Japan's leading museums. Here, the television cameras focus on examples of the great art of the past, draw out their beauty and show comparisons — while a commentator explains and appropriate classical music plays in the background.

For the six-year-olds, there is a television series called "Let's Play with Rhythms" — a sort of rhythm and dance course. There are also scientific programmes for the older children — anatomy courses, for example, or chemistry courses. Here, the television camera takes the youngsters into magnificently-equipped laboratories of the sort that most of the world's schools don't even dare dream about. Here they can watch experiments that involve equipment too expensive for their own schools.

In another successful programme, "The State of Nature", children were given explanations of various geographical features. They were shown how volcanoes were formed, why tides rise and fall, and many other natural phenomena. In addition to using photographs, films, models and experiments, programme planners made a maximum use of real objects, and these were sometimes viewed through microscopes. Though the scale of experiments was limited by available studio facilities, good results were obtained.

In "Our Bodily Structure", the functions of various organs such as the heart, lungs, stomach etc., were shown in individual programmes. Here again the results were good as long as there was plenty of movement in the pictures on the screen. Emphasis was placed on demonstrations in the studio.

Each week, the "Saturday Club" has entertained young audiences with drama, ballet, instrumental music, choirs, gymnastics and recitations presented by semi-professional drama groups of children or by pupils from the schools.

Television is eminently suited for such educational work. It is practical and it is appealing. For Japan's young students, educational television is a new lively medium that backs up teachers and textbooks in a truly vivid fashion.

A Letter from Great Britain

TECHNICAL CHANGE AND THE NEED FOR AESTHETICS

TECHNOLOGICAL Change—Bane or Boon? This was the basic question posed by the *Courier* in the July 1953 issue which highlighted some of the human problems involved in attempting to bring about technological change in under-developed countries. In a letter to the Editor, Mr. David Hardman, former Member of Parliament of Great Britain, has commented on one aspect of this vast problem — "the aesthetic needs of a civilized society." Mr. Hardman's stimulating remarks, we feel sure, will interest our readers in all countries, and we are pleased therefore to publish his long letter almost in its entirety on this page.

Dear Sir,

MAY an inveterate reader of the *Courier* since its inception in 1948 congratulate the Editors upon their July issue? It contained, it will be remembered, a remarkable article by the distinguished anthropologist Dr. Alfred Metraux on the dangers associated with technical change, and a further eight full pages on the human problems which are bound to arise with the impact of industrialization from the West upon the so-called backward peoples. It is symptomatic of Unesco's vital work in these fields that the *Courier* has in the last three years been paying more and more attention to technological change and should in 1953 devote almost an entire number to sagacious thinking on the subject.

I think it necessary, however, to add a few thoughts on the aesthetic needs of a civilized society—a subject hardly touched upon in these discussions on the fundamental question Dr. Metraux and the Editors pose—is technological change a bane or a boon? When I speak of "a civilized society" in this context I am, of course, referring to the civilizing effects or otherwise of industrialization. In the West we have learnt through bitter travail that an industrial revolution can provide very great benefits to humanity and at the same time deprive it of the things of the human spirit. The crying need of our time is that industrialization should create its own culture and at the same time zealously preserve the cultures of the past. The civilizations of the Middle East, the East and of Africa, now vigorously applying scientific method and technology to their own economic conditions, should be warned of our failures and omissions in the West.

No one can stop, nor would wish to stop the changes now taking place. The only way in which the vast populations of the earth can rid themselves of poverty, improve their food supply, improve health, and develop better physical welfare in all its aspects, is by the methods of scientific and technological advance, but the fundamental need of the human spirit is that there should be a *humane* industrialization. Robert Bridges, the English poet, says that the rest of humanity has "seen the Electric Light i' the West". Let mankind profit by its gleam and probe into the shadows that it casts.

For the life of Man is not only founded on technology and science but on art and religion. Alfred Whitehead, the great philosopher, mathematician and educationist, says that "all four are interconnected and issue from Man's total mentality". If human physical welfare is the goal of technical assistance we cannot do without applied science. But there is equal need for aesthetics and the humanities if the profound psychological and spiritual malaise of the great industrial cities of the West is to be avoided. Science has directed attention to *things* as opposed to *values*.

It may be a proud distinction that the industrial civilization of the West should begin with the industrial revolution in England but it has left a trail of evils from which the English have been trying to extricate themselves for the last fifty years. These evils arose from the aesthetic errors of scientific materialism, as well as from the natural greed of men which it intensified. As Whitehead says in his *Science and the Modern World* when speaking of the early industrial system here or in Europe and America, "The point which I am insisting on is the stone-blind eye with which even the best men of that time regarded the importance of aesthetics in a nation's life. I do not believe that we have as yet nearly achieved the right estimate."

(U. N. photo.)

There is no doubt that the vast populations of the earth can improve their conditions of living by applying modern scientific and technological methods, but "the fundamental need is that there should be a humane industrialization"

Speaking on this theme in London in 1946 (since commented upon by Mr. T.S. Eliot in his *Notes towards the Definition of Culture* page 105: 1948) I said that the age of industrialism and democracy had brought to an end most of the great cultural traditions of Europe, not least that of the visual environment, and that fortunes and power had been obtained by exploiting ignorance and appetite. As a result the majority of people in the contemporary world were half-educated, if that, and there was a vast cultural breakdown which stretched from America to Europe and from Europe to the East.

Mr. Eliot comments that "half-education" is a modern phenomenon. "In earlier ages the majority could not be said to have been "half-educated" or less: people had the education necessary for the functions they were called upon to perform. It would be incorrect to refer to a member of a primitive society, or to a skilled agricultural labourer in any age, as half-educated, or quarter-educated or educated to any smaller fraction." The supreme danger of industrialization without humaneness is that diversification among human communities will be wiped out, age-long cultures—invaluable for the Odyssey of the human spirit—will be wiped out, and there will be no contemporary culture with its roots in the past to take their place. The "half-educated", in Mr. Eliot's sense, will inherit the earth.

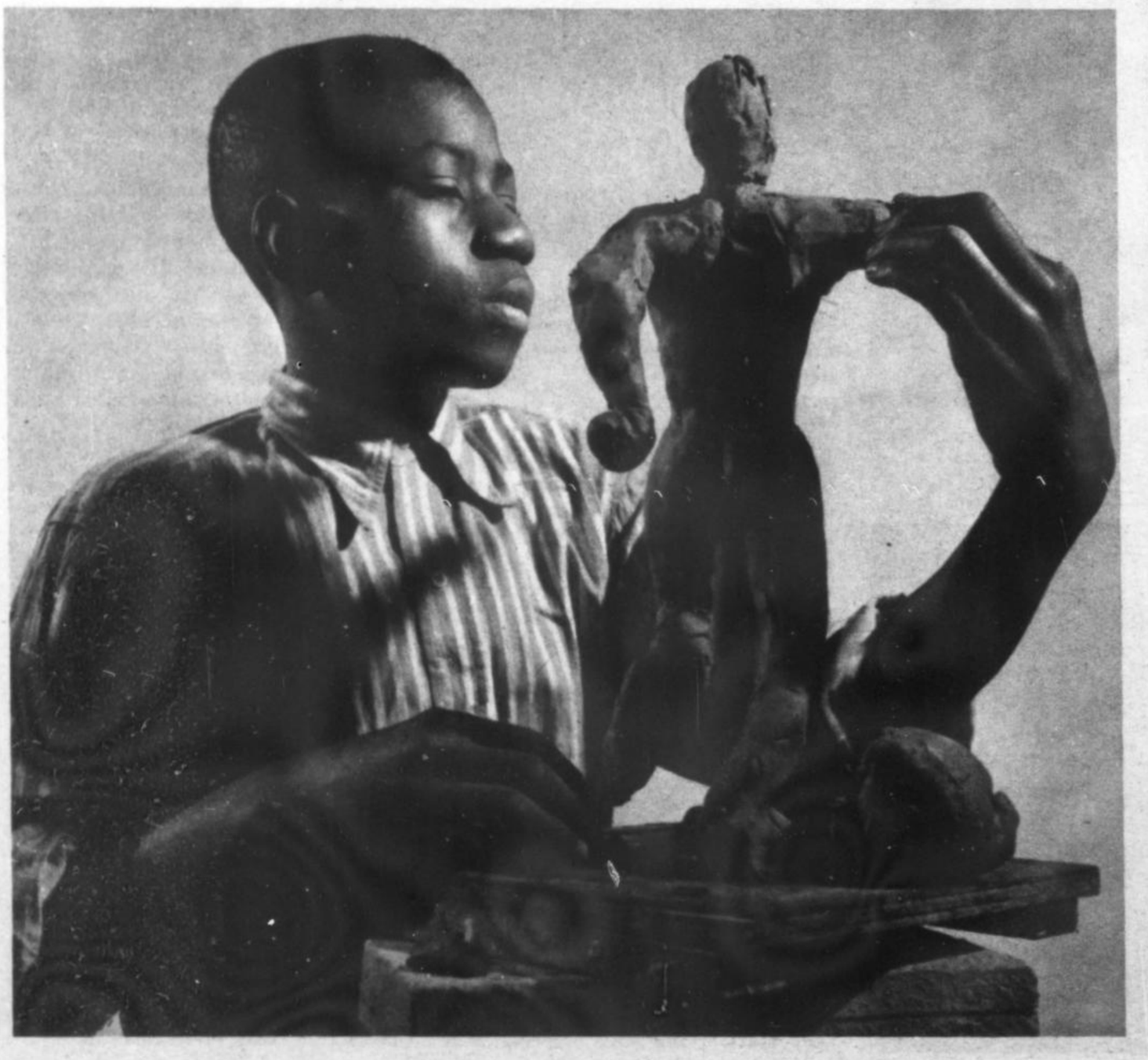
Dr. Metraux remarks on the danger arising from the enthusiastic impatience of the most highly cultivated representatives of the coloured races "who protest most vehemently when white men advise them to maintain their traditional customs". The warning is timely. Power to benefit the material welfare of mankind can come from science and technology, but happiness, as the many diverse cultures of the world have proved through thousands of years of trial and error, is a tender and more wayward plant, requiring the inspiration of the arts and religion.

Wherever technology is introduced there must be corresponding attention given to town and country planning, architecture, the design of goods in daily use (especially those mass produced) if the ugliness and malaise of Western industrial centres is to be avoided. Community planning should have cultural objectives as well as technical. Not only the Temple but the school and the adult college should be the centre from which the aesthetic and spiritual life should be drawn, and when I speak of school and college I am thinking not only of education through discourse, but of activity, first-hand experience and observation, so closely identified with Technical Assistance, as the July *Courier* schows.

Activity, the giving as much chance as possible of children and adults doing things for themselves, is vital. This applies equally to aesthetic and intellectual pursuits as well as physical. Those working in the fields of Technical Assistance should always be aware not only of the impact of technology on primitive communities, but of the frightening influence of the passive amusements of the West—the cinema, sound broadcasting and now Television. These can and do serve their turn in aesthetic and spiritual education of the right kind, but they can be deadly in their effect of cultural uniformity, in their squashing of individual and group initiative, and in their drab tyranny over the realm of aesthetics.

Yours sincerely,
David Hardman.

Man lives not by technology and science alone. He is nourished by the arts and religion as well. In every society whatever its level, these four factors cannot be dissociated if happiness is to accompany material welfare.



"ORIENTEERING..."

...WITH MAP AND COMPASS OUTDOORS

GIVE my daughter Marguerite, aged 12, a compass and a map. Tell her there is a lovely lake, a few miles away, where the fairies and "Little Men in the Woods" used to play, where she can have a picnic with her friends. Or suggest that she go with them to that farm three miles across country where there is a new brood of chickens. The girls will start across country and find the lake or the farm.

They may not get there the fastest or easiest way, but with compass and map they will find a safe track and will not get lost. An expert would probably find a better road and take a bit less time. But the point here is that Marguerite and her friends, town-bred girls as they are, will take to the country and the woods like ducks to water. This is largely because they have studied "Orienteering", which is both a sport and a school subject in Sweden. With their "Silva", (the simple compass with protractor every child in Sweden seems to possess and which Marguerite got for her ninth birthday), map-reading, the spotting of landmarks and the art of following a set course are familiar to them.

The growth of "Orienteering" (the name is taken from Swedish and anglicized by the addition of an extra "e"), is one of these remarkable developments which show how much can be done in education with a simple idea, intelligently applied. "Orientering" as the Swedes write it, is essentially the art of finding your way with map and compass. It has now become something more than that: since it is now a compulsory subject in the schools its educational value has been greatly increased.

Like all things in education and sport, Orienteering is best started early and you must catch the child young. That is why in Swedish schools, where children begin at the age of seven, the first principles are taught in the first year. This is done by easy indoor and outdoor games whose object is simply to give the children a sense of direction and observation.

Diagrams and plans, they are told, are really maps. They draw a diagram of the classroom, a map of the school and school grounds, then a real map with simple lines and landmarks. Elementary pacing and measuring of distances also comes in. For practice, after-school walks and Sunday outings soon enlarge the range of interest.

In the next two or three years, map symbols are learned. Then the orienteering lesson turns into a geography lesson, with incursions into topography, geometry, mathematics, drawing, the drafting of reports and nature studies.

The experience of teachers in Sweden and elsewhere provides interesting indications on the educational use of orienteering.

"The drawing of simple maps", a country schoolmaster in Central Sweden says, "is in my opinion the best introduction for children to the study of geography. The young child seems to take to drawing maps as he does to drawing pictures. From the plan of the school room or school grounds, he will soon be looking at the country around as he would a map. His interest and understanding of maps showing the country and the world is then easily and rapidly encouraged".

Another teacher has emphasized for me the interest of the new school subject for social studies: the child is stimulated by it to learn much more than he would otherwise about his own community, his own country and the different aspects of other countries.

Lessons and practice in "Orientering", as it is called in Sweden, have made this boy familiar with the symbols of cartography. On the blackboard he is drawing a map of last Sunday's outing to a nearby lake (Insjön means "the lake" in Swedish). (U. N. and Unesco photos).

Still another teacher, in a report sent to the educational authorities in Stockholm, stresses a different aspect of the educational value of orienteering: by inducing children to observe landmarks, both on the maps and in nature, their capacity to describe what they see is put to good use. This particular schoolmaster found that children were more willing to write about their outing if they were left to find the road. They find new interest in the history of landmarks, in the nature surrounding them.

Educators both in Sweden and in Canada have been working out other practical methods for using the compulsory teaching of orienteering in the schools in other studies. It is thought better at first not to encumber young pupils with difficult explanations about the compass and its geometrical applications while teaching its use in class. (One teacher found that instead of 360 "degrees" his pupils were talking about highways by their compass number: number 90 indicating East, 180 the road South, etc.). At later stages, the use of geometry for taking bearings and measuring heights and distances comes in and is learned with added interest because its usefulness has been seen in practice with map and compass and on orienteering outings.

The possibilities of combining orienteering with nature studies, botany and animal life are also easily understood by teachers and children. Notes on things observed on an orienteering cross-country walk have greatly added to the value of this new subject which was first regarded only as a sport and which is still regarded by most of its practitioners as primarily a source of fun.

Even the original idea of orienteering, conceived some 30 years ago by Major Ernst Killander, constituted an interesting educational advance. Major Killander, a Swedish youth and scout leader, had been worried at the amount of time the young people he was looking after were spending watching sport instead of participating in it. One Sunday morning, he gave each of them an objective they could reach with the help of a compass and a topographical map of the country-side: they could go as they liked, by the main roads, or across hill and dale. The idea was a success and the Swedes now look upon orienteering as a national sport —as golf is British, hockey is Canadian and baseball American.

In Sweden today over 350,000 people (including 135,000 adults) take part every year in orienteering contests. As in Sweden, orienteering has become a compulsory school subject in Ontario Province, Canada. Booklets exist on orienteering sport and the Swedish orienteering manual published in 1943 sold 150,000 copies. An amusing illustrated manual has just been published in German in Switzerland, and the illustrated leaflets on the "Silva" compass which provide elementary instruction on map-reading are printed in four or five languages.

But the practical usefulness of orienteering goes far beyond sport, games and exercise. Its educational value is more and more recognized. For children of Marguerite's age, it is a way to start gaining confidence in the country, a wonderful sport and a fascinating way to discover the world around.

Yves DU GUERNY

It is a commonplace experience in Sweden to find children, singly or in groups, finding their way across the countryside with the aid of a compass and a map. Much more than a game, map-reading and orientation with the aid of a compass are now an integral part of the Swedish school programme. This instruction begins in the primary school with simple problems and is developed to include more advanced mathematics, natural history and botany. (Unesco photos.)

FROM THE UNESCO NEWSROOM

SPORT: Unesco has just requested its sixty-nine Member States to offer suggestions on how best to develop the use of sports for educational purposes. The Member States were also asked what they are already doing in this field. Various possible Unesco actions were suggested for the countries to consider. One was the question of whether Unesco ought to organize comparative studies on the place of sport in different educational systems. Member States were also asked whether, in their opinion, such an Unesco action should be linked with an international occasion in sport, such as the Olympic Games of 1956

★ **BRAILLE BOOKS:** *A new method of Braille printing, known as "solid dot" Braille, which will print three times as fast as the present embossing system at one-third of the cost is being tried out in England by the National Institute for the Blind. The system makes possible a printing rate of 5,000 sheets an hour and may ultimately cheapen considerably the printing rates for Braille books. These will also be less bulky, as thinner paper can be used and printed on both sides.*

THEATRE CLASSROOM: A large open-air theatre is to be built at Tasquillo, Hidalgo, Mexico, to aid the fundamental education activities of the mission of the Inter-American Native Affairs Institute in the Mezquital Valley. The pageants and plays shown will be based on the traditions of the Otomi Indians, but will be blended with lessons on better health and living conditions.

★ **TECHNICAL EDUCATION:** *A wood industry school, the first of its kind in Switzerland, has been inaugurated in the Canton of Bern. It is fully equipped and its curriculum includes ordinary training courses and ad hoc short specialist courses based on current needs of the wood industry.*

AIRBORNE CLASSES: The Science Faculty of the Sorbonne University in Paris is making airborne-classes —an idea it first tried out a few years ago—a permanent feature of its curriculum. Airborne studies of atmospheric disturbances and cosmic rays were found particularly valuable. Experience has shown that students can learn more in one flight than in many hours spent examining maps. So far these educational flights have only been made over France, but others are now planned over Switzerland, Sweden, Holland and Belgium.

★ **HIGHER EDUCATION:** *Representatives of over 100 Spanish-speaking universities in Spain and America met recently at Madrid and Salamanca. Among the questions they discussed were the equivalence of university diplomas and degrees, the place of humanism in university training and the co-ordination of scientific and university research.*

NEWSPRINT: Heat from the depths of the earth will provide the power for New Zealand's first large-scale newsprint mills, now being built at Te Teko (North Island) and which will start producing paper in October 1955. These mills will be unique in the history of paper-making, in that hot springs will provide an inexhaustible supply of high-pressure steam both for heat and to drive the turbines for electricity. This will mean a yearly saving of several hundreds of thousands of dollars in coal costs alone. The plant will produce 75,000 tons of newsprint and 36,000 tons of pulp yearly—enough to fill New Zealand's needs and provide a surplus for other Pacific countries.

★ **MUTUAL UNDERSTANDING:** *Some 75 institutions of higher learning in the United States have been studying how to use their facilities more effectively to further international understanding. They have been appraising their language, geography and political science courses in the light of present world conditions and in such matters as student exchanges, foreign service training, research and adult education. These studies have been carried out in connection with a project for the Carnegie Endowment for International Peace. Dr. Howard E. Wilson, director of the project, estimates that there are already over 600 International Relations Clubs, and 200 to 300 United Nations Clubs, with a total membership of at least 100,000 students, connected with American colleges and universities.*

LITERACY: More than 7,000 collective literacy centres have been established in Mexican communities according to a report compiled on the fourth anniversary of Mexico's law providing for a compulsory campaign against illiteracy. Another 3,000 such centres have been set up to supplement the work of regular schools. It is calculated that more than 3,000,000 adults have been taught to read and write in the course of the four-year campaign.

★ **FREE SCHOOLING:** *The Kashmir Government has announced that from now on all schooling will be entirely free, "from kindergarten to the doctorate degree". There are ten colleges and thirteen hundred and forty-nine primary schools in Kashmir with a total of 110,000 pupils.*

AGRICULTURE LESSONS: To help develop agricultural teaching in primary schools, the Spanish Ministry of Agriculture is offering a number of prizes to teachers. These will be awarded to primary teachers who succeed best in imparting to their pupils a love for agriculture.

★ **OVERSEAS STUDIES:** *At least 85,000 persons left their own country in order to study at university level abroad last year, according to a Unesco inquiry. In 1951-1952, North America and Europe between them welcomed 38 % of the world's total of such persons, their respective shares of this percentage being the same.*

YOUNG SCIENTISTS: To gather scientific data about winds, waves and tides, and specimens of submarine flora and fauna, pupils from Walford Secondary School near London made an expedition to the North Sea this year. They embarked on six fishing trawlers at the port of Grimsby, and the party included their geography teacher and a biologist and his pupil assistant. The aim was to see if the children were able to make practical use of what they had learned in class and to do genuinely useful research.

★ **STUDY ABROAD:** *Nearly 1,000 United States students will have a chance to study abroad under government scholarship grants during the 1954-1955 academic year, according to a spokesman of the Institute of International Education. The awards are made under the Fulbright and Buenos Aires convention programmes, which are part of the international exchange activities of the U.S. Department of State.*

TEACHERS NEEDED: Last year the Gold Coast introduced free compulsory primary education—an important step for a young, independent country. To meet the shortage of primary teachers, it is planned to open six new teacher training colleges and to double the enrolment at the six existing ones. About 6,000 primary teachers will thus be trained each year.

★ **MUSIC FESTIVALS:** *Europe's most famous musical performances are to be made available to American audiences by means of frequency modulation broadcasting and special long-playing recordings. Sixteen of Europe's most important music festivals have agreed in principle to the project. The plan is under the auspices of Geneva's European Cultural Centre. The recordings are to be made during actual festival performances, and then distributed in the United States as a sort of "Festival of the Month", much like books distributed through literary clubs.*

READING PRIMERS: A series of special reading primers for Aboriginal children in Australia's Northern Territories is being produced by the Commonwealth Office of Education. Illustrated in colour and using a carefully controlled English vocabulary, the primers—the result of three year's experiments—will be accompanied by activity material and notes for teaching.

★ **MUSIC EDUCATION:** *A training centre for travelling music teachers who work in small country schools has just been opened near Paris by the Federation of Rural Music Centres, whose aim is to provide every child in the scattered rural schools with the widest possible music education.*

Courses include: history of music, harmony, instrumental work, singing and choral classes, and dancing. A general cultural course with visits to theatres and concerts, lectures on the theatre and theatre diction, a study of rural activities in the field of the cinema, theatre, and a course on teaching methods are also given.

ART IN SHIPS: In Norway, art is being taken into the workshop and down to the sea in ships. A society known as "Art in the Workshop", of which some 50 industrial concerns are members, now has 50 small circulating exhibits which tour factories throughout the country. In the newest built Norwegian cargo-liner "Buenos Aires", reproductions of works by contemporary Norwegian artists are being hung in all the cabins, while another new cargo vessel, the "Moria", has water colours and etchings in both officers' and crews' messes and lounges.

★ **RACE RELATIONS:** *A Chair of Race Relations is to be established at the new Central African University now being built at Salisbury, Southern Rhodesia. The Chair will be endowed with funds raised by the Central African Round Tables, part of a worldwide non-political organization with similar aims to the International Rotary. They have undertaken the project because they feel that unhampered research and teaching in an atmosphere of freedom and goodwill can bring about greater mutual understanding wherever people of diverse races, beliefs and customs are living side by side.*

The Central African University, whose foundation stone was laid in July this year, will when opened accept students on their merits irrespective of race, creed or colour.

PEN FRIENDS: To encourage and develop correspondence between schoolchildren in different countries, the Austrian Government has issued a special postage stamp to be used exclusively for such correspondence.

★ **MATHEMATICS:** *The Association for Teaching Aids in Mathematics (Leicester, United Kingdom) is keeping teachers informed on developments in this field through a series of bulletins. These bulletins record methods and details of apparatus, which are being used or tried out in primary, secondary and technical schools, and colleges and universities, both in England and in other parts of the world. Thus teachers who have already produced valuable teaching material will be able to make their work available for consideration by others.*

SCHOOL EXCHANGES: The Ministry of Education of Lower Saxony states that more than 5,600 boys and girls in this *Land* of the German Federal Republic were corresponding abroad last year. During the year, there was a great increase in the number of secondary teachers (664 as compared with 287 in 1951) and secondary pupils (3,946 as compared with 1,929 in 1951) who were able to stay in foreign countries.

★ **ESPERANTO:** *Classes in Esperanto were held in Zurich in the form of a university extension course earlier this year. Similar classes were being held in other European cities — Copenhagen, Brussels, Strasbourg, Paris, London, Manchester, Stuttgart, Florence, Parma and Salzburg. All the classes were working on the same syllabus, and the students were thus able to correspond with each other and to form friendships.*

VERNACULAR LANGUAGES: In British African territories alone, the International African Institute lists 369 languages or dialects. In South America, one expert lists 94 linguistic groups and some 558 languages. In India, some 100 different languages are spoken and 14 are recognized as official regional tongues. The existence of these hundreds of languages has created an enormous and complex problem for teachers who are trying to apply the principle that the education of schoolchildren and adult illiterates is best carried out through the mother tongue of the pupil. It was with these problems in mind that Unesco recently published a 154-page book, "The Use of Vernacular Languages in Education".* Presenting an analysis of various solutions, along with considerable background information, the Unesco book also contains a classified bibliography and an index, as well as a list and tentative classification of the languages spoken in the world today.

★ *"The Use for Vernacular Languages in Education"; 154 pages. Price:* $1.00; 6/-;

THE MUEZZINS CALL THE FAITHFUL FOR B.C.G. VACCINATION

THE Muezzins from their minarets of Iraq have added a new chant to their age-long call to prayer. It is the call to BCG vaccination relayed through loudspeakers perched on the minarets, to the Faithful entering the Mosques with their prayer mats rolled beneath their arms.

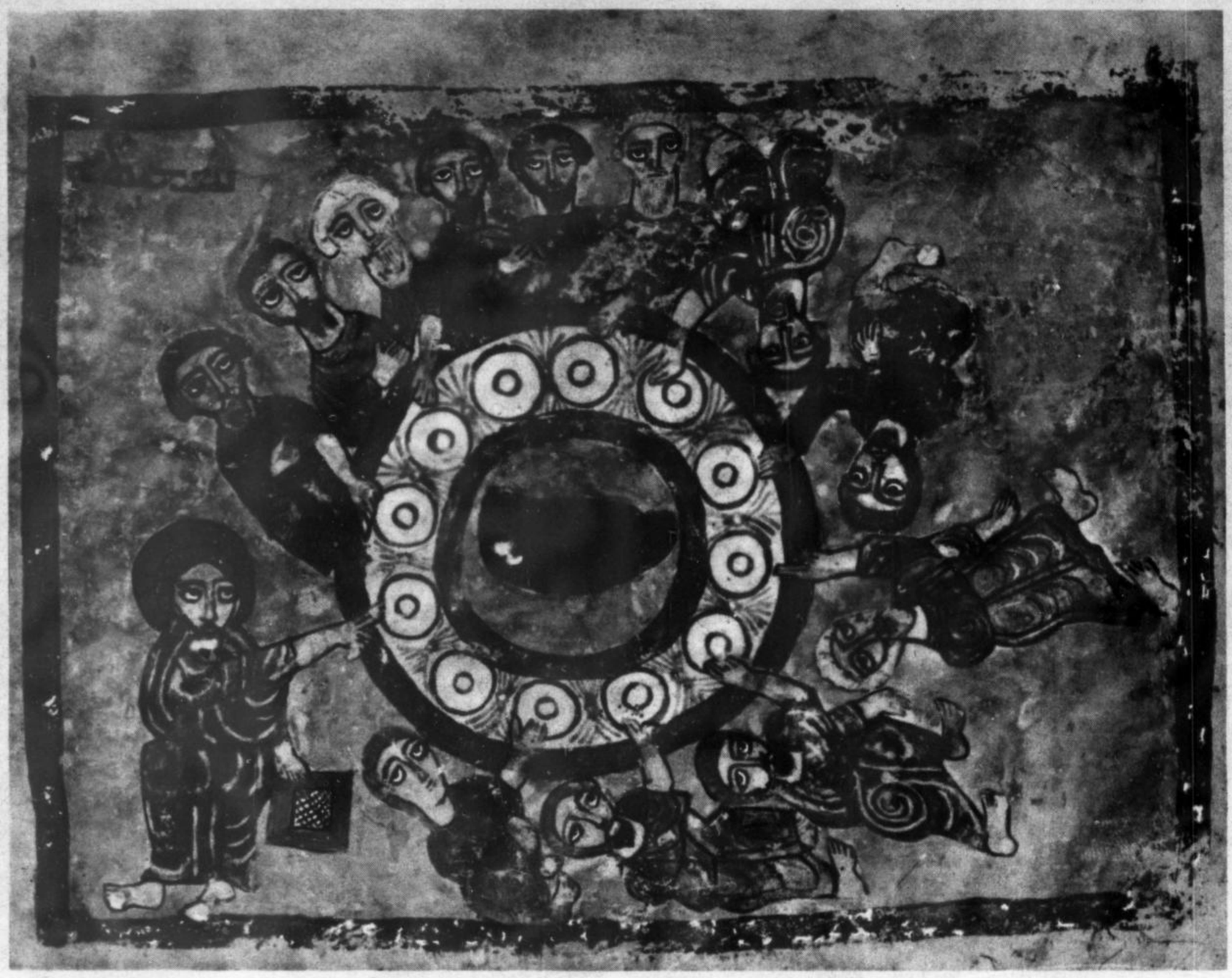
This is the first time that the Muezzins of Kut, Kufa and Nedjef have broadcast worldly matters in the same breath as holy events. It is a sign of the importance Iraq is placing on mass tuberculosis control for her people. No method has been overlooked in an effort to inform the whole population of this campaign aided by UNICEF (United Nations Children's Fund). Ancient methods of town-criers and house-to-house canvassing are as valid as the latest 20th century techniques for mass propaganda.

Iraq is one of 6 Middle East countries and is among 32 countries of the world currently aided by UNICEF vaccines, transport and medical supplies and receiving WHO (World Health Organization) technical guidance, in the fight against tuberculosis.

(Photo copyright Editions Arthaud, Paris.)

Christian Art Near Eastern

CONTACTS BETWEEN CULTURES



"THE LAST SUPPER". This picture on a 12th century manuscript now in the British Museum, is taken from a series illustrating the life of Christ. The clumsiness and naïvety of the drawing mark it as the strangest of all the Syriac manuscripts which have come down to us. It recalls certain Egyptian friezes, but it also has a modern quality which finds an echo in some present-day art trends. Especially striking are the faces with their wide-open eyes. (Photo British Museum.)

by Abbé Jules Leroy

"In the Middle Ages", said Victor Hugo, "there were no profound, important thoughts which were not inscribed in stone."

In this phrase, the author of *Notre-Dame de Paris* not only gives us the reason for the multitude of figures and scenes decorating the portals of our cathedrals or enlivening the multi-coloured panes of their stained-glass windows, but also reveals the educational significance of the image up to the time of the invention of printing.

In this sense, the "Middle Ages" covered a much longer period than is generally understood by the term, going back to the first manifestations of the "civilization" of those prehistoric men who produced the cave paintings of Altamira or Lascaux and lasting until the introduction of a new means of expressing ideas.

Until that time, the art of writing was the prerogative of the learned. It presupposed such a standard of learning that those who were able to write were necessarily the most influential people in the State, and it is for that reason that the oldest civilizations may truly be described as civilizations of scribes and priests, both of whom held the secret of the art of writing. The common people's only means of acquiring knowledge was to listen to instruction given by word of mouth or to read the lessons in history and ethics, set forth by the recognized custodians of knowledge, in bas-reliefs and frescoes.

Paintings and sculpture simply embodied in a visual form, suited to yet untutored minds, truths now accessible to all, thanks to the increase in the

(Continued on next page)

"THE CANONS OF EUSEBIUS" or **"THE CONCORDANCE OF THE GOSPELS"** (A.D. 1177). The marginal drawings inspired by mosaic flooring have a Hellenistic style full of poetry. From this point of wiew, they differ greatly from the religious character of those usually found in liturgical books. (Photo L. Jalabert.)

"THE RAISING OF LAZARUS" (A.D. 1216/1220): The theme is borrowed from Byzantine iconography, but Eastern influence is seen in the faces and costumes. The Realism contrasts strongly with the traditional style of Constantinople church paintings with their cold, hieratic Byzantine figures. (Photo British Museum.)

"THE NATIVITY". This is one of the finest pictures from a manuscript on which the painter, in accordance with Byzantine religious rules, has grouped all the events relating to the birth of Christ: the angel appearing to the shepherds, the adoration of the Magi, the bathing of the new-born child. It is one of the most noteworthy examples of the meeting of Byzantine art with pre-Mongol Arab art, traces of which are to be found in the faces. (Photo British Museum.)

ARAB FLAVOUR ADDED TO THE TRADITIONAL THEMES OF EARLY RELIGIOUS ART

(Continued from previous page)

"CHRIST'S ENTRY INTO JERUSALEM". This Syriac manuscript from the Vatican Library, dating from 1546, is a strongly stylized copy of a 13th century miniature. (Ph. Vatican Library.)

number of printed books. They filled the place in instruction that films and television are tending to take at the present time, a process which may one day end in their ousting the book and replacing the civilization of the printed word by that of the visual image. A curious repetition of history by which modern man is placed in the same situation as his distant ancestors and is better able to understand Victor Hugo's words of genius than were the poet's contemporaries!

It was hundreds of years before man was able to free himself to some extent from the ascendancy of the image. Visual depiction was found everywhere, and took a particularly brilliant form in all the civilizations of the Near East or the Mediterranean. All the successive empires in Egypt, Mesopotamia, Greece or Rome, like all the religions, made use of it.

When Christianity made its appearance in the *oikoumene,* i.e. the civilized inhabited world as distinct from the "barbarian" world, it took a place in the system of instruction everywhere prevailing and created a world of images drawn from biblical history which, in its eyes, recounts the whole story of the bringing of salvation to the world, first by the Jewish people and later by Jesus Christ. It covered the walls of its churches with these images and scattered them through the pages of its manuscripts, so that, as one of the Fathers of the Greek Church was to say in the fifth century, "the dumb image spoke from the wall" or from the margin of the book with as much authority as the written word itself.

"THE FOUR EVANGELISTS". A meeting of civilizations is reflected in this manuscript fragment. The features recall those of certain figures in friezes at Turfan, Central Asia, while the draping of the robes and style of furniture are those found in the Arab miniature. This manuscript probably dates from the 12th or 13th centuries. (Property of Mr. Kevorkian, New York; photo by John D. Schiff.)

All the images here displayed to the reader are drawn from this world of sacred representations. They all come from the Christian societies of Mesopotamia, where the Christian religion was introduced at a very early date. The first centre from which it spread was the little kingdom of Edessa, the modern Urfa, which officially adopted Christianity at the end of the second century. From that ancient stronghold of Semitic culture, little affected by the Hellenic civilization from which it was cut off by its language, Syriac, akin to Aramaic and Hebrew, it spread throughout all the countries watered by the Tigris and the Euphrates.

"MOSES CONFERS WITH PHARAOH", a Syriac manuscript, now in the Bibliotheque Nationale, Paris, and one of the oldest of its kind, probably dating from the 6th century. This illustration is taken from a Bible containing both the Old and New Testaments. This small work is classed today as one of the last relics of Hellenistic painting adapted by the Christians of Syria and Mesopotamia. (Photo : Bibliothèque Nationale.)

In the fifth century, during the theological disputes concerning the nature of Christ, a schism occurred between the various churches whose only remaining sign of their lost unity thereafter was the language they shared. While most of the churches of Upper Mesopotamia adopted Jacobite monophysitism (1), those in Persia went over to Nestorianism (2) (now represented by about 100,000 adherents in North Persia and East Turkey in the neighbourhood between the Lakes of Van and Urumia).

In the Middle Ages, this Nestorian Church in Persia played a brilliant part. Its missionaries spread Christian communities throughout Central Asia, China and even Tibet, though these communities were to disappear in the Mongol invasion of the thirteenth century, so that the European missionaries who came out in the 17th and 18th centuries found virgin soil awaiting them.

This spread of the Syriac-speaking Nestorian Church in the Far East is extremely interesting, because it shows us a meeting of civilizations which has left its mark and explains the existence in Far-Eastern thought of ideas recognizably drawn from Persian Christianity. The same lesson can be gleaned from the Syriac manuscripts enriched with miniatures which, in the absence of wall paintings now vanished, help us to define, or at least sketch in (for these manuscripts are rare, most of them having been destroyed by wars or other calamities) the various cultural movements which have taken place in Mesopotamia. The history of these venerable fragments is an epitome of the history of Mesopotamia since the introduction of Christianity: each of the alien civilizations with which this region has, willy-nilly, come into contact, has left its mark upon it.

The interest that these miniatures from the Syriac manuscripts have for us probably lies far more in this than in their aesthetic quality, which is governed by the laws of book illumination as understood in the early Middle Ages and now, after long neglect, coming back into favour with some of our contemporary artists. The art of the book is a two-dimensional art. There is a disturbance of unity if three-dimensional figures are incorporated in the text. This accounts for the fact that the figures overlap instead of receding in perspective, for slight differences in their size and the absence of relief and shadow.

These laws, which were observed by all painters up to the revival of painting, were applied by these Mesopotamian artists in a highly individual manner. In the oldest manuscripts, for instance —those of the sixth century—they give life, by their expressive gestures, to the cold, hieratic Byzantine figures, while in the thirteenth century they give an Arab flavour to the traditional themes by introducing backgrounds, faces or dress borrowed from their own people and environment, or again themselves create images whose "primitivism" is echoed in some of today's art.

For all three reasons, this religious imagery deserves to be better known. It will thus regain a part of its original function, which was to teach. Only the sort of instruction it provides will have changed. While in the past it was theological or religious, today it is historical and cultural.

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(1) The belief that the human and divine natures in Christ are united in one single nature, part human and part divine.

(2) The doctrine of Nestorious, patriarch of Constantinople in the 5th century, who held that there were two persons as well as two natures in Jesus Christ—the divine and the human.

WARDHA : CENTRE OF GANDHIAN THOUGHT

by Dr J.D.N. VERSLUYS

Unesco Social Science Representative for South Asia

Gandhian ideology regards the family and the village as the natural setting for human life. With help and advice from social workers and handicraft teachers trained at the Wardha Centre (seen here at mealtime), villagers can learn to become self-supporting and improve their standards of health and of living.

WARDHA is a small town, 70 miles south of Nagpur, the capital of Madyah Pradesh. This means Central Province, and Wardha is indeed the geographical centre of India. It is also the centre of Gandhian thought. Here, too, are situated the buildings of the All-India Village Industries Association —one of the material results of Mahatma Gandhi's teachings.

When I entered the gate leading to the Association's buildings the first thing I saw was a *Pieta*, a sculpture of the Virgin Mary holding the dead body of Christ in her lap, carved out of granite—a symbol of Christianity I hardly expected to find in the heart of India.

But this was soon explained by Dr. J.C. Kumarappa, the outstanding Gandhian economist, as he showed me round the village industries centre he has directed for many years. Gandhian ideas, he pointed out, are not linked to any particular religion and therefore followers of any religion whether they are Hindus, Buddhists, Moslems or Christians, are all welcome at Wardha.

The central precept of the Gandhian ideology—non-violence—not only implies the generally accepted sense of the term, but also the deeper and wider meaning that nature should not be roughly curbed at will. It teaches that man should adapt himself to nature in order to establish a real harmony. This attitude signifies reluctance to follow any artificial ways of life such as are found in large cities.

The family, preferably the joint family (where brothers and sisters with their families are living together as a single group), and the village are regarded as the natural setting for human life. The conditions required to maintain this structure call for both the family and the village to be self-sufficient. Therefore as far as possible everything used in the village should be manufactured by the villagers themselves. To meet the principal need —textiles—spinning and weaving are taught. But other handicrafts are also encouraged, and one of the main purposes of the Wardha Centre is to teach social workers and the teachers of handicrafts.

There is another reason for this interest in handicrafts. It is realized that the enormous rural problem of under-employment and complete unemployment cannot easily be remedied. The proportion of cultivators to arable land is increasing unfavourably and each year the population pressure becomes more serious.

Industrialization cannot solve the problem, as only a relatively small number of workers can be absorbed in big industries. Such industries would require heavy capital investment, and capital is scarce in India. Moreover, Dr. Kumarappa feels that big industries are not in keeping with India's own culture, which flourished during many centuries in various handicrafts until these were suppressed by the cheap machine-made products of Western industry. Gandhi and his followers, therefore, had economic, cultural and national reasons for propagating the revival of village handicrafts.

As is well-known, hand-spinning became the symbol of Gandhism in the "twenties", and in the Museum at Wardha various models of spinning-wheels, besides many beautiful products of hand-weaving and many other handicrafts are displayed. Hand-spinning gradually gained an importance far beyond its probably doubtful economic usefulness. It became the symbol of nationalism and even took on an almost religious significance. But today the Wardha Centre tries to develop simple and more efficient village tools to enable the villagers to obtain better results more economically.

This is nowadays one of the chief purposes of the Centre which tests various tools, compares implements from different parts of the country, and then sets out to modify or combine them in order to give village industries a better chance against the competition of machine-made products. I was shown a bullock-driven oil press whose efficiency had been improved 60% by a change in design costing very little and by the introduction of ball-bearings.

When I asked Dr. Kumarappa if he did not resent the use of these ball-bearings, which after all are machine-made products, he replied frankly that big factories were certainly useful for some specific purposes, but that their use should be limited to those products which could not be made by hand. The Centre uses scientific methods to improve village tools, but it always keeps one condition in mind, namely, that to be within the reach of the village artisan, the improved tools must be cheap, and require no power supply for their operation.

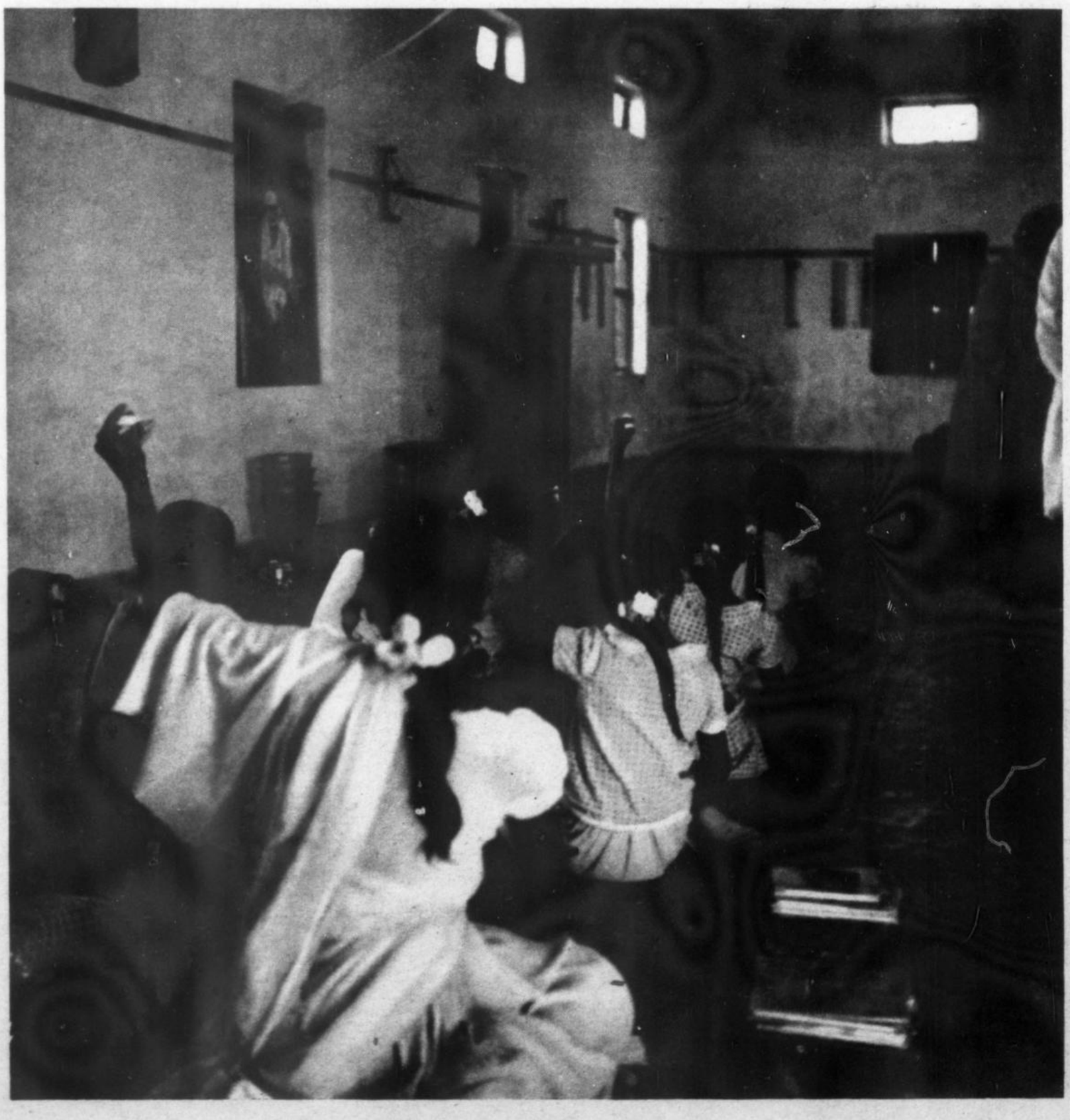
Paper-making is also demonstrated at Wardha. Although an ingenious system is used to make the bullock-driven mill as efficient as possible, the product is about 50% more expensive than machine-made paper. Yet paper-making as a handicraft is taught for it enables the villagers to make use of various sorts of refuse (old rags, straw, etc.), which would otherwise be thrown away, and it prevents the people from using their money outside the village economy. This is just one example of action based on the principle that consumption must be adapted to village productive capacity. This in turn implies that the village must be ready to accept a lower satisfaction of its needs from local production than would be the case if it sought goods manufactured in the cities.

There is another feature connected with the campaign for handicrafts which should be mentioned, namely, the educational advantages. The Gandhian system of education, called basic education, makes wide use of "learning by doing". It lays down that the child should first of all understand those things which form the background of life in the village and therefore the teacher should use the children's immediate surroundings as his starting point.

Spinning, for instance, may lead the teacher to explain how cotton grows and to describe all the other processes connected with the cultivation and use of this crop. From here he may pass on to the mechanical principle of the spinning-wheel and then to the economic issues of buying cotton and selling yarn, etc. This system naturally requires a great deal of effort on the part of the teacher, but has certainly the advantage of being a far more direct approach to the subject matter.

The Wardha Centre has not only done useful work in developing village industries, but also by teaching social workers to approach village life as a whole and through all its aspects—agriculture, health, education and culture.

In India, hand-spinning became the symbol of Gandhism and took on an almost religious significance. At Wardha, which is both the centre of Gandhian thought and of the All-India Village Industries Association, the tradition continues. The centre's main purpose, however, is to develop simple and efficient village tools and to improve craft and agricultural techniques.



YOU CAN HELP A SMALL CHILD

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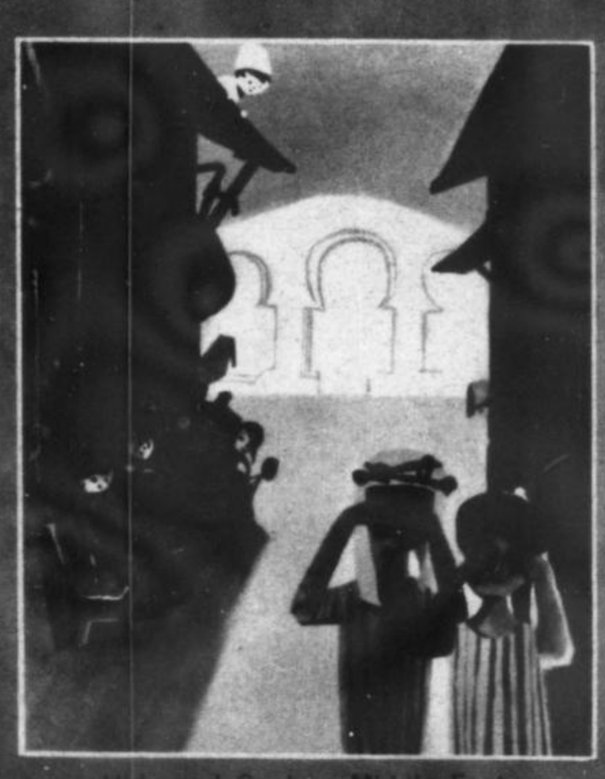
THE celebration of Christmas and the New Year as a season of goodwill is continuously expressed in old and newer forms. Among these is the fairly new custom of sending greeting cards. Youngest of all, is the custom of world-famous artists to lend their talent to the design of cards for the UN Children's Fund—cards which will bear warm wishes to absent friends, and buy protection against disease and malnutrition for children in 75 countries of the world. Under the name of Lewitt-Him, two Polish-born London artists (photo, left) have contributed five illustrations for this year's UNICEF greeting cards. In rich, warm colours, they show "Children at Play" in five countries of the world receiving UNICEF assistance. During 20 years of partnership Jan Le Witt and George Him have gained an international reputation in the fields of mural painting, book and magazine illustration. They are known to thousands of children in France, Britain, the United States, Sweden, Poland, Israel and Hungary through their illustrations, and it is now the turn of millions of the world's less fortunate children to benefit from their talents. For each box of ten cards sold (7/6d; $1.00 or 350 French francs) will enable UNICEF to provide enough BCG vaccine to protect 24 children against TB; or enough powdered milk to give 9 children a glass every day for a week; or enough UNICEF penicillin to treat eight children for yaws; or enough DDT to safeguard 13 children from malaria; or enough vaccine to protect 33 children against diphtheria. The subjects of the cards illustrate the universality of children's games, and range from hopscotch in Pakistan to kite-flying in Peru, from hide-and-seek in the Middle East to games in the Philippines and Greece. But in each of these countries there are many sick and needy children who cannot join those games. To heal Asia's sores, to rid Peru of typhus, to bring relief to Middle East children and aid Greece's earthquake victims, besides protecting Pakistan from the scourge of tuberculosis and malaria, this is but a fraction of the work among 20 million new children which UNICEF will undertake this coming year, with technical help from the World Health Organization. Created in 1946 by the UN General Assembly to bring emergency aid to the children of Europe and other war-devastated areas, UNICEF has since developed into the world's largest international effort to improve the health and welfare of children and mothers. The work of UNICEF is not for some remote tomorrow. It is for today. Through the sale of these cards, today, you can be helping UNICEF to raise standards of health and welfare for children and thereby play a part in the fulfilment of the promise implicit in the United Nations of a better future.

Information as to where UNICEF Greeting Cards can be purchased is obtainable from any of the United Nations Information Centres throughout the world.

Hop-Scotch—Pakistan.

Blind-Man's Buff—Greece.



Hide and Seek — Middle East.

Kite Flying—Peru.

Greased-Pole—Philippines.

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